ARCHAEOLOGICAL INVESTIGATIONS AT TOSAWIHI, A GREAT BASIN QUARRY

Part 3: A Perspective from Locality 36

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Errata sheet

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Re: IMR #639 report: *Archaeological Investigations at Tosawihi, A Great Basin Quarry. Part 3: A Perspective from Locality 36.*

The title page of this report omitted the name of one author.

C. Lynn Rogers should be added to the list of contributors.

ABSTRACT

This report is an archaeological study of one of more than two hundred prehistoric bedrock quarry and quarry-related localities known administratively as the Tosawihi Quarries (26Ek3032). Results are discussed in the context of recent survey, testing, and data recovery in the quarry district. Debates over hunter/gatherer resource acquisition strategies focused investigations on the economic aspects of quarrying and toolstone processing. A cost/benefit model emphasizing return rate maximization is evaluated and the archaeological evidence for a cost/benefit extraction and processing strategy is considered.

The site and its environmental setting are described, and field methods, artifacts, and recovery contexts are discussed. Quarrying processes, site formation, and feature and artifact patterning are addressed. The final chapter summarizes work at Locality 36 in light of information derived from previous studies at and near the Tosawihi Quarries. Issues unresolved by present and previous work are addressed as potential avenues of future inquiry.

The excavation and analysis of Locality 221, a small site located near Locality 36, is included in the report.

CULTURAL RESOURCES MANAGEMENT SUMMARY

Intensive minerals exploration, extraction, processing, and transport are elements of the Ivanhoe Project, currently in progress in Elko County, Nevada. The project is located on public lands administered by the Elko Resource Area of the Bureau of Land Management, and subsumes the Tosawihi Quarries (26Ek3032; cf. map), a portion of a district eligible for nomination to the National Register of Historic Places.

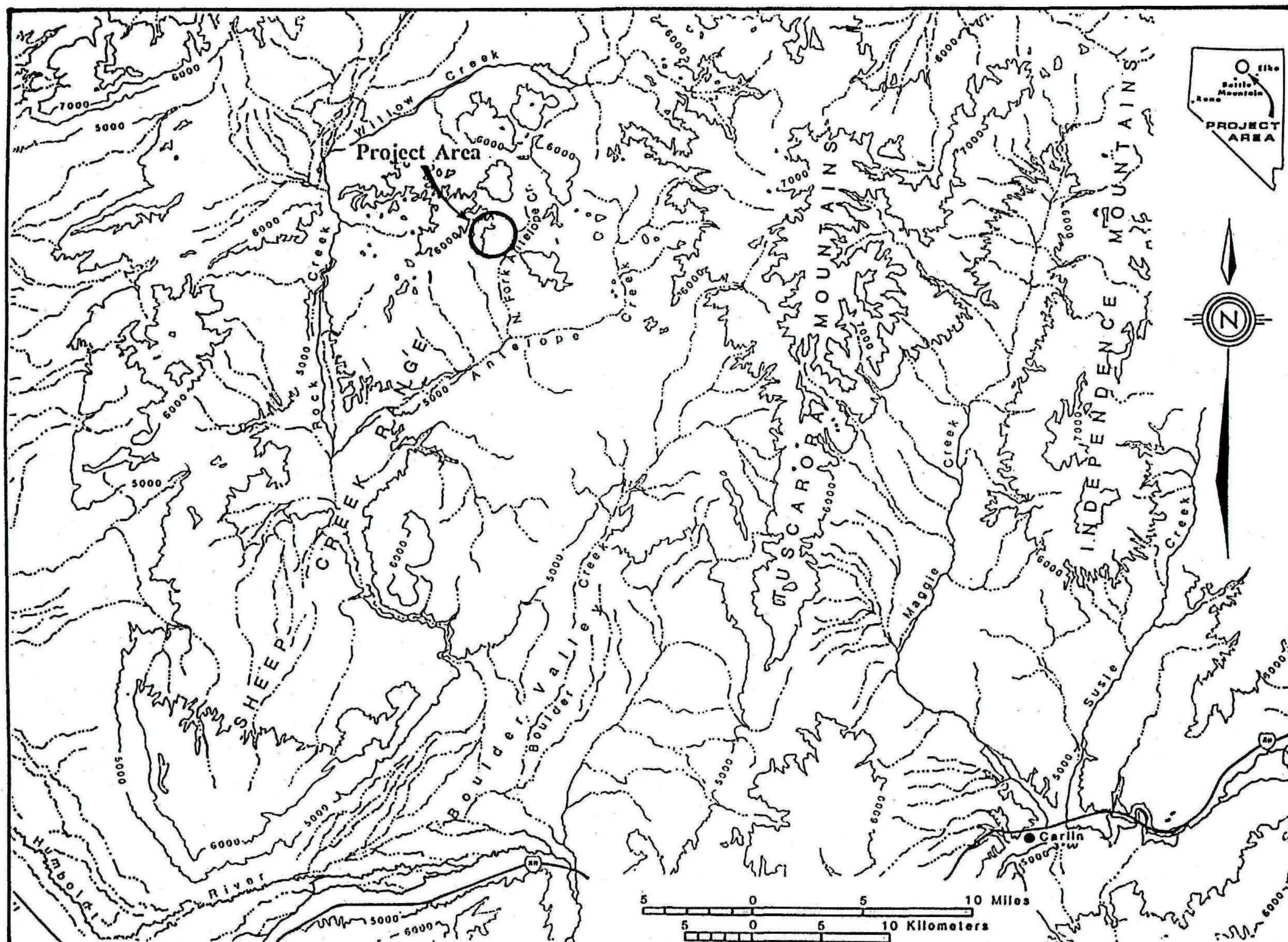
Since 1987, Intermountain Research has conducted archaeological survey, testing, and mitigation (Elston, Raven, and Budy 1987; Intermountain Research 1987, 1988a-d; Zeier 1987; Budy 1988; Drews 1988; Elston 1988a-b, 1989; Raven 1988; Elston 1989; Elston and Raven 1992) triggered by Ivanhoe Project development and funded by the Ivanhoe Gold Company. Proposed development of an access road, an office compound, and a causeway across Little Antelope Creek Canyon prompted development of a data recovery plan for 17 localities in 26Ek3032 (Intermountain Research 1988a, c). Subsequent project design changes removed several of these localities from the plan of operations, however, and their planned mitigation was cancelled. Later, Ivanhoe Gold Company determined that full development of its USX East pit design would intrude the southern margin of one of the most intensively quarried localities at Tosawihi (26Ek3032, Locality 36), and that construction of pit-to-causeway access would obliterate a small reduction locus (26Ek3032, Locality 221). With several years of intensive Tosawihi research completed by this time, it was deemed appropriate to revise the data recovery plan for Locality 36 in light of an evolved understanding of quarry complex archaeology. Thus, an amendment to the original plan was prepared (Intermountain Research 1990a), and a separate data recovery plan was prepared for Locality 221 (Intermountain Research 1990b).

The work reported here refers specifically to the mitigation of Locality 36, a complex of more than 50 prehistoric quarry features in the southeast portion of the Tosawihi Quarries, and of Locality 221. Field work began in late July 1990, and was completed in late September 1990, employing a crew of 20. The crew devoted 744 person days to the field effort. Data recovery at Locality 221 was accomplished concurrently.

The amended data recovery plan called for detailed photogrammetric mapping of the locality using low altitude aerial photographs, close order survey (2 m transect intervals) of the locality, plotting, flagging, and surface collection of formed artifacts, and plotting and inventory of features. At the end of field work, 60 quarry features and 37 reduction features had been mapped and inventoried, and 462 surface artifacts had been plotted and collected.

As directed by the data recovery plan, systematic, judgmental, and probabilistic sampling techniques were employed where appropriate. Surfaces of selected quarry pits were sampled systematically by cruciform transects of small (25 cm^2 or 50 cm^2) surface scrapes. Debitage size, density, and distribution across the locality were sampled by a stratified, random placement of small (25 cm^2) surface scrapes (shovel skimmed to 2 cm below surface). Lithic reduction features, both observed on the surface and exposed during test exercises, were sampled by randomly selected surface scrapes and judgmentally placed excavation units. In order to reduce sample size and the handling of debitage, some lithic samples were split in the field and only the portion needed for further analysis and documentation was transported to the lab and analyzed.

Quarry pit complexes were exposed with relatively short backhoe trenches, subsequently intersected by perpendicular trenches to facilitate segregating quarrying episodes. Profiles and column samples were prepared and qualitative analysis of extraction and reduction debris was conducted.



Ivanhoe Project Area map.

Extensive surface scrapes, accomplished mechanically by a front loader and a road grader, were of two types: deposits of quarrying debris were removed to bedrock at selected quarry pit complexes to check for charcoal deposits and reveal the extent of quarrying in bedrock, and about 30 cm of soil was removed from approximately 3600 m^2 in the northeast (non-quarrying) portion of the locality to expose buried hearths and other features. Revealed hearths were collected for flotation and recovery of charcoal for radiocarbon dating.

Data recovery at Locality 221 was considerably less complex. The site was surveyed, artifacts and features were mapped, and a detailed contour map was prepared. Ten randomly placed 50 cm x 50 cm surface scrapes retrieved a sample of surface artifacts, and three excavation units explored for buried quarry features adjacent and away from the outcropping opalite.

Data recovery procedures proposed in the data recovery plans are compared in Table A to those actually executed. Discrepancies between proposed *minimum* numbers of units and actual units employed are explained in table footnotes.

Table A. Proposed and Actual Data Recovery Procedures Executed at Localities 36 and 221.

Procedure	Proposed Minimum Units	Proposed Maximum Units	Actual Units
Locality 36			
Total Random Sample Surface Scrapes[a]	600 25 cm^2	600 25 cm^2	562 25 cm^2 [b]
Systematic Cruciform Quarry Pit Sample Surface Scrapes	300 25 cm^2	300 25 cm^2	67 50 cm^2 [c]; 57 25 cm^2
Sample Surface Scrapes in Quarry Pit Features		120 50 cm^2	4 1 m^2
Sample Surface Scrapes in Non-quarry Pit Features		120 50 cm^2	56 50 cm^2; 2 1 m^2
Test or Block Excavation of Features in Non-quarry Pit Areas		50 1 x 1 m or 1 x .5 m EUs[d]	25 1 x 1 m EUs; 3 1 x .5 m EUs; 61 .5 x .5 m EUs
Backhoe Trenching	150 m		265 m and 3 1 x .5 m EUs at trenches
Locality 221			
Total Random Sample Surface Scrapes[a]	10 50 cm^2		10 50 cm^2
Test Excavation Units adjacent Bedrock Exposure	3 1 x 1 m		3 1 x 1 m

[a]Shovel-skimmed to 2 cm below surface
[b]Final locality boundary definition permitted fewer than the estimated 600 units
[c]25 cm^2 units were inappropriate where reduction debris consisted of very large debitage; thus, 50 cm^2 units were employed where necessary
[d]Excavation Units

In April, Intermountain Research returned to Locality 36 to monitor topsoil removal from the southwestern margin of the site in anticipation of pit excavation by the mining company. The aim was to recover charcoal deposits for radiocarbon assay not encountered during data recovery and to examine subsurface deposits for buried features. No bedrock pits, charcoal, or formed artifacts were revealed, and the observed debitage appeared to occur only in the upper five to ten cm of deposit, probably an artifact of downslope transport.

Commencing in September, 1990, cataloguing, analysis, and draft final report preparation were undertaken; the work was completed in January, 1992.

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FIGURES

TABLES

ACKNOWLEDGEMENTS

Third in a series reporting archaeological research funded by Ivanhoe Gold Company, this volume is a consequence of a 1990 Intermountain Research expedition to Tosawihi mounted at the behest of the Bureau of Land Management. Numerous folks associated with each organization have come and gone since the Tosawihi endeavor began and others have persisted, but all have left their mark on the work.

Ivanhoe Gold Company, the Bureau of Land Management, and the Nevada Division of Historic Preservation and Archaeology have supported all phases of the research in important ways. We are grateful for their confidence.

Directed by Robert Elston, this phase of the Tosawihi program was designed by a team composed of Elston, Kathryn Ataman, William Bloomer, Steve Botkin, Eric Ingbar, Melinda Leach, Christopher Raven, and Dave Schmitt. Dan Dugas served as project stratigrapher and C. Lynn Rogers managed collections. Report production was accomplished by Raven (editing), Katherine Nickerson (text production, layout, and bibliography management), Mike Drews and Evangeline Elston (drafting), Ingbar (computer graphics), Bill Germino (artifact photography and photographic plate production), and Cari Inoway (artifact illustration). Denise Bisiaux-Lopez provided administrative support and Cashion Callaway served as project manager.

Field and laboratory personnel included, in addition to those mentioned above, Steve Erven, Susan McCabe, Mark Moore, Glenn Thackery, Alison Wiens, Caitlin Carroll, Kris Carambelas, Dennis Gray, L.L. Holmes, Margaret Hangan, Jana Hembree, and Tina McAffee. Mike Baldwin cooked and Dave Singleton saw to camp support and served in the trenches. Heather Davis, Evangeline Elston, and Alan McCabe volunteered in the field and we thank them for it.

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A number of Western Shoshone people visiting Tosawihi in the summer of 1991 supplied us with insights from which this report has benefitted.

Chapter 1

RESEARCH DESIGN

Kathryn Ataman, Kristopher R. Carambelas, Robert G. Elston, Eric E. Ingbar, Melinda Leach, and Christopher Raven

ficta voluptatis causa sint proxima veris.
—Horace

fervet opus
—Virgil

The Tosawihi Quarries complex (26Ek3032) in central northern Nevada is among the largest prehistoric bedrock toolstone quarries in North America. It encompasses more than 800 acres, and at least a thousand more adjoining acres are littered with the detritus of toolstone processing. Volcanic tuff at Tosawihi was transformed by hot spring activity into cryptocrystalline, conchoidally fracturing "opalite", a high quality chert (Elston 1992a). The material was utilized as toolstone over the past 8000 to 10,000 years, and it travelled, by transport or trade, at least 175 km from the quarries.

Our research at Tosawihi began in 1987 with intensive surveys, followed by tests (1988) and a program of data recovery (1989), but until we studied Locality 36 (1990), a component of the sprawling Tosawihi complex, most of our work had been peripheral to the heart of the quarries. Most of the archaeological sites we examined were camps and workshops to which toolstone and partially worked bifaces were transported and further reduced (but not used) before export from Tosawihi, few quarry sites were studied.

We assumed that prehistoric hunters and gatherers generally employed strategies of effort that minimized costs and maximized returns (Elston 1992b), so we pitched our inquiry to consider how those factors might have affected seasonal scheduling, the lengths of visits to the quarries, the structure of subsistence activities supporting the venture, and the reasons for locating particular kinds of sites in particular kinds of places. We also examined the process of biface manufacture and the form of the products exported; we employed various modes of technological and morphological analysis, and we rallied both ethnographic and experimental data to estimate the time and effort required to quarry and process toolstone into exportable form. All this was done from afar, however, and we were aware that our studies were a little like trying to infer something of city life by looking only at the suburbs.

When we came to work at Locality 36, we confronted downtown reality. Perched on a ridge and slope at the southern margin of the Tosawihi complex, the site reflects a tumult of activity stunningly different from any we had studied before (cf. Elston and Raven 1992). Great, deep floods of debitage wash across the surface, emanating from more than fifty prehistoric quarry pits. Over some five acres, splashed with broken opalite, we found the direct record of at least 4000 years of toolstone procurement. A 30 m wide band of shallowly buried opalite bedrock parallels the ridge just below its crest, and the relative ease of access to fine lithic material invited millennia of revisitation; somewhat away from the stone source, up on the flats of the ridge top, we found dozens of reduction stations and even a few hearths.

The present project allowed us not only to evaluate our previous work, but also to build upon it. Here, we look closely at the actual business of quarrying opalite at Tosawihi, discovering which tasks were involved and how they were organized. We also place Locality 36 in larger regional contexts to help understand how quarrying fit into the annual round of prehistoric and protohistoric peoples. Like other researchers, however, we have found that understanding quarries is daunting, especially at large complexes. The sheer volume of artifacts overwhelms the observer. Quarry deposits are often deep, with complicated stratigraphy, and the lack of chronological control impedes interpretation. We are challenged, however, to confront these methodological problems by the great information potential of quarries.

The Importance of Quarries for Prehistoric Archaeology

Hunter-gatherer archaeology frequently and explicitly invokes chipped stone technology to examine trade and exchange, territoriality, group interaction, mobility patterns, and other aspects of prehistoric adaptation (cf. Goodyear 1979; Spiess and Wilson 1989; Morrow and Jeffries 1989). Although the acquisition of toolstone is usually assumed to have been important, such studies seldom consider information from quarry locations or other sources of stone tools. This is regrettable, because quarries are not merely sources of insight into prehistoric lithic technology, but also may inform on prehistoric economics, craft specialization, production organization, technological change, and other substantive issues whose domain extends far beyond the toolstone source itself (Jochim 1989).

Many technological questions that depend on prehistoric technology for answers cannot be addressed *without* reference to quarry data. Often, there is more than one way of producing a particular chipped stone form, so lithic technology cannot be reconstructed entirely from final products (Callahan 1979). Artifacts found most often at sites away from raw material sources are final products, broken in use. Therefore, unfinished tools discarded in manufacture and debitage collected from quarry sites provide technological information often not obtainable elsewhere.

Quarries not only provide necessary technological information, but also can be sources of data on prehistoric organizational patterns. The intensity of toolstone extraction and production, the seasons of quarry use, and the frequency of quarrying forays can, for example, be used to test hypotheses concerning mobility strategies, settlement patterns, labor organization, and trade or exchange. Examining quarries as if they were special cases of "limited activity sites" prematurely ends their utility for archaeological research.

A Brief Survey of Quarry Studies

The following survey is intended to show that, compared to other archaeological phenomena, the relatively few quarry studies almost exclusively employ technological perspectives. A few studies (e.g., Reher 1991; Torrence 1986), however, have tried to link quarries to larger questions of regional economics; we attempt both approaches here.

Much New World descriptive quarry literature dates from the turn of the century, when Holmes (1892, 1897, 1919), Wilson (1897), and Fowke (1928) addressed the antiquity and nature of some of the largest North American quarries. They considered prehistoric quarrying techniques, tools, and technological organization. There have been few substantive contributions since this early work, although changes in research orientations, the rise of modern dating techniques, and the availability of mechanized earthmoving equipment have swollen the roster of potential questions that can be addressed with data from quarries.

Many North American quarries, unlike Tosawihi, entailed the excavation of raw material blocks from a soil matrix. Studies of quarries relying on easily exploitable surface or near surface deposits (Singer and Ericson 1977; Elston and Zeier 1984; Flenniken and Ozbun 1988) have focused primarily on trade patterns, territorial limits, or lithic production systems; the time, effort, and strategies involved in extraction methods have not been considered.

The situation at Tosawihi differs vastly; toolstone occurs in bedrock deposits, and high quality material is difficult to extract. We did not realize fully the difficulty of bedrock extraction until we performed our own quarrying experiments (Carambelas and Raven 1991; Elston 1992b). While our output doubtless might improve with additional practice, time and effort involved in quarrying clearly are significant factors of bedrock quarrying. This has stimulated our interest in strategies of toolstone extraction and processing, and in the broader economic aspects of quarrying.

Two of the largest prehistoric quarries in North America are the Knife River source in North Dakota and Spanish Diggings in Wyoming, both of which are estimated to cover several million square meters. Artifacts of Knife River chert are found over a wide area of the continent. This high quality toolstone occurs as cobbles in deposits of glacial outwash covered by loess. Studies of the utilization of the Knife River source (Ahler and Christensen 1983; Ahler 1986) are among the most detailed in the literature. Much of this work deals with the problem of analyzing large quantities of debitage to identify reduction stages, distinct lithic industries, technological organization, and the regional travels of the flint through the Plains and Midwest. It also deals with some of the quarry-specific questions we have examined at Tosawihi, such as quantities of extracted material, quarrying techniques employed, and labor requirements for extraction. Since the geologic setting is so different from Tosawihi, however, the data is not directly comparable.

Spanish Diggings in Wyoming is a vast bedrock quarry complex the size of which is estimated in the millions of square meters (Reher 1991:273). This site, larger than Tosawihi, has been examined only superficially, yet the brief descriptions available suggest it has similar quarry features and debitage densities. Questions of fall-off in density and material type, mobility patterns, task organization, and regional patterns of raw material distribution have been proposed (Reher 1991), but their research has not begun.

European quarries are more often similar to Tosawihi, and have undergone extensive study. The Neolithic flint mines of Grimes Graves in Norfolk, England, cover about 34 acres and date to ca. 2500-1400 B.C. The flint in these pits and shafts with radiating pits and adits consists of high quality nodules embedded in a solid chalk matrix. Of three horizontal flint strata, the lowest is of the highest quality, extending to a depth of 12 meters. Grimes Graves was investigated as early as 1870 and as recently as 1972 (Mercer 1976; Sieveking et al. 1972), and several pits and shafts have been archaeologically excavated entirely. Quarrying tools recovered are very similar to those found at Tosawihi and to those replicated and used in our experimental studies (Schmitt 1992a; Carambelas and Raven 1991). The physical constraints of quarrying, at least in the early components of Grimes Graves, probably resembled those encountered by prehistoric quarriers at Tosawihi. Once identified as a quarry complex, the primary questions asked of Grimes Graves involved quarrying techniques, dating and changes in the nature of quarrying through time, task composition, and excavation and productivity rates. There has been little effort, however, to fit intensive quarrying activity into regional settlement patterns and economies.

Tosawihi is the largest known silicified bedrock toolstone source in the Great Basin. Other quarries include the Lake Range quarries in northern Washoe County, Nevada (Pedrick 1985; Clay 1988), the Sinter Hill Quarry near Reno, Nevada (Elston and Turner 1968), chert quarries in the Cortez Mountains, Eureka County, Nevada (Pierce and Chapin 1987; Livingston and Pierce 1988), the Coleman Locality (Tuohy 1970), a basalt quarry and workshop in Washoe County, Nevada, and the Sugarloaf Obsidian Quarry in southeastern California (Elston and Zeier 1984). Numerous other quarries are reported but not described, and others undoubtedly remain undiscovered.

A number of recent edited volumes have addressed various issues of lithic procurement and processing, reflecting increased interest in the subject (Ericson and Purdy 1984; Ellis and Lothrop 1989; Butler and May 1984; Vehik 1985; Sieveking and Newcomer 1987; Hester and Shafer 1991; Henry and Odell 1989; Torrence 1989; Johnson and Morrow 1987), but they include almost no in-depth description of the processes and techniques involved in prehistoric bedrock quarrying. Exchange systems and territoriality, lithic trajectories, mobility strategies, toolstone conservation strategies, and optimization models are addressed and proposed, but without rehearsal of the warranting data. Thus, while our research focuses on the economic aspects of quarrying, the lack of descriptive data in the general literature prompts us to describe in detail the quarrying techniques used by the prehistoric quarriers of Locality 36. We intend to describe toolstone procurement and processing at the locality, test a general model of procurement and processing strategies, and place our results in a regional context.

Previous Research At Tosawihi

Chronological data at Tosawihi are provided by radiocarbon dates and temporally sensitive artifacts such as projectile points and ceramics. Obsidian hydration also is used to suggest artifact dates, but only relative to other artifacts from the site, since there is no effective hydration calibration to absolute age. Hydration and technological studies support the basic chronological validity of western Great Basin point chronologies (Elston 1986a; Thomas 1981; Elston and Drews 1992). These data suggest that the earliest visits to the quarries (represented by stemmed points, thought to have been in use between 10,000 and 8,000 B.P.) were infrequent, and may have been unrelated to toolstone exploitation. The frequency of use and the dominant pattern of use (toolstone exploitation via associated support sites) increased gradually throughout the Archaic and expanded dramatically in the Late Archaic after 1500 B.P.

The geographical sources of temporally diagnostic obsidian artifacts suggest that groups exploiting Tosawihi may have had different geographical ranges or trade networks through time. Pre-Archaic Stemmed Series obsidian points came primarily from the Brown's Bench source in southern Idaho, with a few from rare or unknown sources; Early and Middle Archaic points came almost entirely from Paradise Valley in northwestern Nevada, and Late Archaic Desert Series points came from Brown's Bench, Paradise Valley, and several rare and unknown sources. The wider range of obsidian sources used in the Late Archaic coincides with the more intensive use of the quarries noted above.

Field work has involved intensive survey of the quarries (Elston, Raven, and Budy 1987) and peripheral areas (Budy 1988; Drews 1988; Raven 1988; Zeier 1987), testing of numerous sites (Elston, ed. 1989), and data recovery (surface collections, surface scrapes, and excavations) at 25 sites (Elston and Raven 1992), most in areas peripheral to the main quarries. Recently, a probabilistic sample survey of 115 km^2 in the Tosawihi uplands surrounding the quarries (10.3%

of the landscape) was completed (Leach and Botkin 1992). These studies have revealed much about the quarries and the ways in which they were used; our research has been guided by models of toolstone procurement derived from microeconomics and evolutionary ecology; they provide the theoretical framework that has shaped the present inquiry.

General Theory

Our model focuses on the economics of toolstone procurement (Elston 1992b). For heuristic purposes, we employ an analytical construct, the *lithic production system* (Ericson 1984:3; Elston 1986b:138), representing the body of individual skills, knowledge, activities, and places having to do with lithic procurement. We further abstract the lithic production system into *components*, such as mobility patterns, schedules, labor organizations, technologies, and techniques of extraction, processing, storage, and transportation. We imagine that foragers confronting cultural and environmental variation (such as size of the annual range, distribution of food resources, occurrence of toolstone, season, and competition with other groups) combine lithic production system components into different *lithic procurement strategies*. Economic models (Christenson 1980; Torrence 1986, 1989), including our previous work (Elston 1992c), assume that a general goal of foragers is to maximize the benefit/cost ratio of toolstone procurement, or to achieve the greatest *efficiency* by lowering the time and energy invested in this activity. We have come to realize, however, that if prehistoric foragers were interested *merely* in efficiency, they would have procured toolstone by less labor intensive means that quarrying at Tosawihi. We must suppose, then, that Tosawihi quarriers invested time and effort in bedrock quarrying *in order to* increase their net rate of return, or *profitability* (Stephens and Krebs 1986:9). We further suppose that rate maximizing strategies are most likely employed to procure resources for which fitness requires some minimum amount within a finite time. In this light, it is interesting to reconsider the goal of several strategies of lithic processing and tool production (use of standardized products, specialist quarriers or knappers, simplified production procedures, optimized product design, structured use of space, and organized task groups) that Torrence (1986) identifies as efficiency-increasing. Because these approaches are all labor intensive, or require much material, or both, they can maximize the benefit/cost ratio (efficiency) only under certain conditions; for the most part, their use increases *net return* (profitability). At the same time, we recognize that constraints imposed by the primacy of food and water in subsistence do not always allow either the maximum benefit/cost ratio of lithic procurement or the greater profit to be obtained.

Environmental variation provides both opportunities and constraints for lithic procurement. For instance, the distribution and occurrence of lithic sources in the landscape, or *lithic terrane*, profoundly affects lithic procurement costs. The lithic terrane can vary along several dimensions that affect the benefit/cost ratio of toolstone procurement; a lithic terrane may contain many sources or none at all, sources may be clustered or widely dispersed, and toolstone quality may range from excellent to poor. Several permutations of toolstone abundance, quality, and distribution are diagrammed in Figure 1a-d; each circle represents an annual range, the curved lines are major streams (along which we assume the greatest concentration of food resources), black circles are good quality toolstone sources, and open circles are poor quality sources.

Modeling lithic procurement strategies, we can hold one constraint constant and vary one or more of the others. Consider the implications for mobile hunters and gatherers operating in the lithic terrane depicted in Figure 1a. Toolstone sources are abundant and widely dispersed throughout the range; even if food and lithic resources are not perfectly congruent, it is not far from any place to a lithic source of some kind. Travel and transportation costs of toolstone procurement are low and the

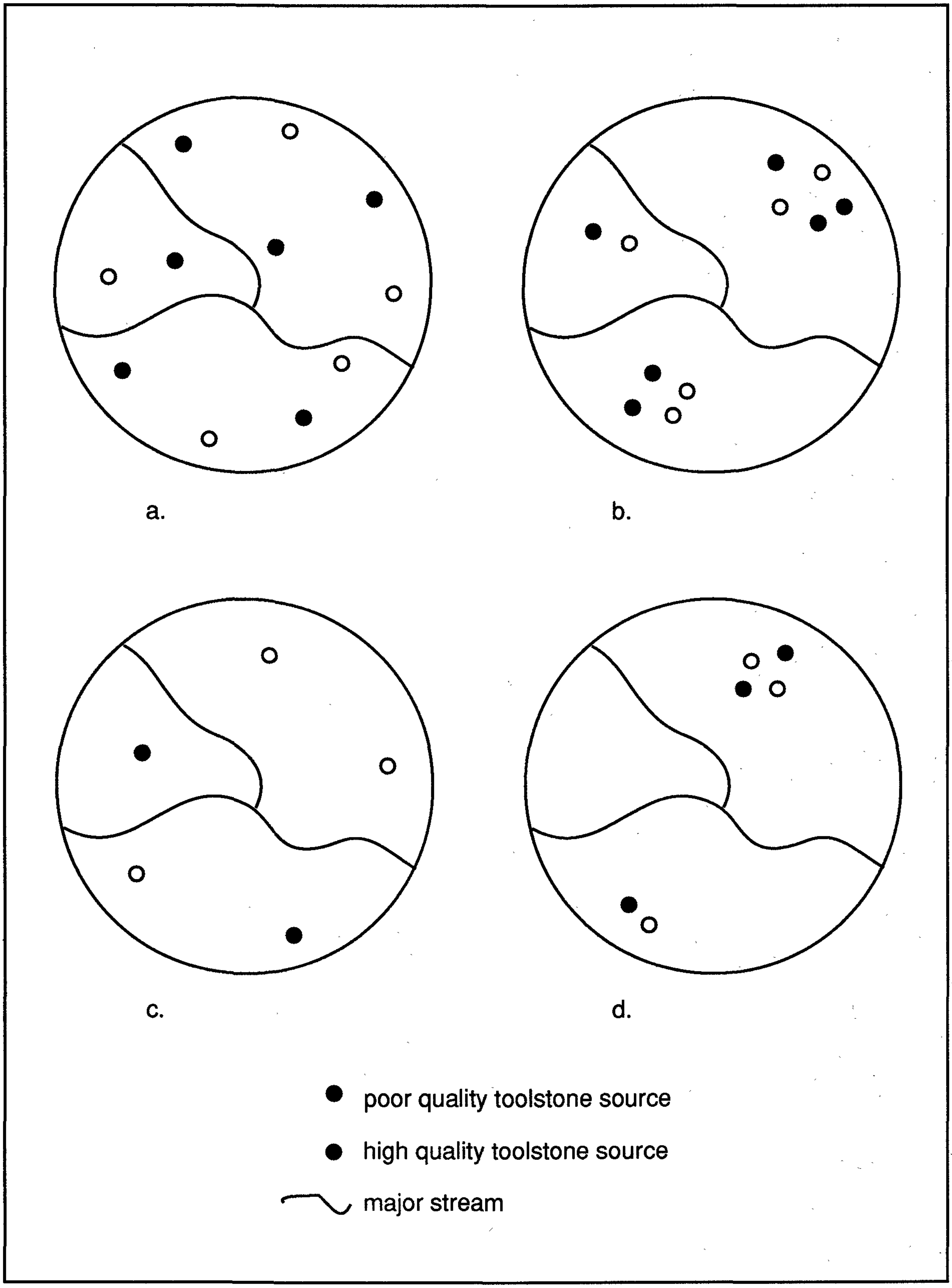


Figure 1. Toolstone distribution models.

need for strategies that minimize procurement costs or extend tool use-life are reduced; lithic procurement frequently can be embedded in forays for other resources. Holding mobility constant, lithic procurement costs, risks, and incongruence between lithic sources and food will tend to increase as lithic sources become more clustered (Figure 1b) and less abundant (Figure 1c), or both (Figure 1d). Foragers operating in poor lithic terranes such as those depicted in Figure 1c-d must plan lithic procurement carefully to ensure adequate toolstone supplies throughout the year. Strategies for dealing with scarce lithic resources dispersed over a large range under conditions of high mobility are exemplified in the portable, flexible lithic toolkits of Paleoindians (Goodyear 1979; Ellis and Lothrop 1989) with design parameters that require the use of high quality toolstone.

Alternatively, we can hold the lithic terrane constant and vary some other factor such as mobility. Consider a highly sedentary group tethered to a small foraging radius around the residential base. Unless a lithic source occurs within that foraging range, lithic procurement will require special logistical forays or must be embedded in forays for other resources. The less abundant and more dispersed the lithic sources, the greater the logistical problems and procurement costs. Even in a rich lithic terrane such as is depicted in Figure 1a, if sedentism results in use of a smaller annual range, access to the best toolstone sources may be limited. Trade may become the only option for procurement of high quality toolstone. Foragers then may choose to use cheaper, lower quality raw materials for most tools while reserving the more costly high quality materials for special purpose tools having high design standards.

Within the broad region east of the Osgood Mountains between the Humboldt River and the Owyhee Plateau, Tosawihi chert is abundant, often dominant, in most Archaic archaeological sites except those near a local toolstone source. All known local sources provided toolstone of quality lower than Tosawihi material, and none was quarried intensively. This suggests a lithic terrane different from any depicted in Figure 1a-d, one containing several dispersed sources of mediocre quality and one source (or clustered group of sources) of superior quality. The lithic procurement strategy employed along the Humboldt River through the Archaic appears to concentrate on Tosawihi chert for most tools when possible. Situational needs, however, often were filled by using local materials, particularly when people occupied a place long enough to consume supplies of tools originally brought there (e.g., James Creek Shelter; cf. Elston and Budy 1990).

By definition, lithic procurement strategies are not invariant. We propose, however, that, other things being equal, the tendency to make similar economic decisions in similar circumstances will result in use of a limited number of strategies in a given region or at a given lithic source, thereby producing a limited number of patterns visible in the archeological record. Nevertheless, specifying the economic factors operating in each element of a procurement strategy is difficult because each may have different currency, constraints, and decision variables. The problem can be simplified by considering the major classes of variables affecting the benefit/cost ratio of toolstone procurement. We define benefits as toolstone returns per procurement foray, and costs as all time and energy expended in travel, extraction, processing, and transportation, as well as lost opportunity. We assume that prudent foragers will seek to improve the benefit/cost ratio of toolstone procurement through strategies that maximize toolstone returns and minimize acquisition costs.

Patterns of Cost Minimization at Tosawihi Quarries

Cost-minimizing goals can be accomplished by manipulating schedules, adjusting organization of labor, locating task sites and residences strategically, and segmenting activities in the interest of efficiency. We thus model cost-minimizing strategies in terms of site placement and activity segmentation, framing our expectations of assemblage content and location in qualitative or relative expressions that can be tested by statistical pattern recognition. For example, campsite position should tend to occur nearer or farther from toolstone source or subsistence resources (water, plants, animals) as duration of occupation varies; certain artifact or feature types are expected to occur with greater or lesser frequency in functionally different settings. This kind of model guided much of our previous work at Tosawihi, where we were concerned with explaining variability in position and content of several residential and workshop sites in areas peripheral to the main quarries (Elston and Raven 1992), as well as in concurrent study (Leach and Botkin 1992) of uplands surrounding them. In these cases, patterns of site location and assemblage content seem related to strategies that minimize costs not directly associated with quarrying.

Most sites investigated in previous work served as support areas associated with quarrying and processing opalite into bifaces. Most bifaces were processed to middle and late Stage 3 and heat-treated, often within a 1,000 meter radius of the quarries. Nevertheless, even at sites as much as 12 km from toolstone sources, much opalite still was being processed rather than used (Leach and Botkin 1992). Modeling processing and transportation costs (Elston 1992b) suggests that performing most processing at or near the source is a strategy that reduces cost and risk and increases net rate of intake.

Lack of extended occupation was expected, because, compared to lowland areas, food and water are scarce at Tosawihi for much of the year, making it difficult and expensive to stay there for extended periods. Residential sites where toolstone processing was incidental to procurement of other resources are absent or archaeologically invisible. With little archaeological evidence for the procurement or processing of non-lithic resources, we conclude that intensive prehistoric use of the landscape focused almost entirely on the acquisition of toolstone.

Nevertheless, people did linger at Tosawihi to extract and process large quantities of toolstone. Our quarrying and processing experiments indicate that to obtain 10 kg of bifaces (the weight of the largest biface cache so far found at Tosawihi), about 300 kg of toolstone had to be extracted and processed, requiring something like 34 person-hours (Elston 1992b). Assuming that the cached bifaces represent toolstone surplus, the total time for extracting and processing toolstone must have been even greater, to which also must be added time for travel, rest, and foraging. Thus, quarrying forays of several days duration for two or more people do not seem unreasonable.

We recognized two kinds of short term residential site immediately peripheral to the quarries, differentiated by content and location (i.e., domestic reduction sites and domestic quarrying sites; Leach 1992). Domestic reduction sites tend to be located central to water, food resources, and toolstone; diagnostic projectile points suggest they were used from the Early to Middle Archaic, with increasingly frequent occupation. They contain abundant and diverse flaked tools, relatively large numbers of millingstones, ceramics, and functionally diverse features, including hearths. Such sites seem to represent occupation of sufficient duration to require compromise in location, convenient to water and local food resources as well as to toolstone. In contrast, domestic quarrying sites are less common, and tend to be located at or near toolstone sources and reduction localities. Compared to domestic reduction sites, flaked tools are less abundant and assemblage diversity is lower; ground stone and ceramics are rare or absent. These sites may be products of less frequent, shorter term occupation by small groups (perhaps logistical parties) camping at or near toolstone sources. The pattern appears to have increased during the Late Archaic.

In addition to the tendency for domestic reduction sites to be located near diverse resources, and for domestic quarry sites to be located near toolstone, the distribution of non-quarry sites tends to be distributed to minimize the costs of travel and transport between sources, reduction stations, and base camps (Raven 1992a). In particular, there tends to be a bi-modal, positive relationship between density of reduction stations and distance from quarries and residential sites—high in both the immediate vicinities of the parent quarry and the camp, low in intervening areas. This trend is not always perfectly expressed, however, owing to topography and other extrinsic factors.

We argued that season of use should be influenced by economic factors that determine when it is least costly to be at the quarries (Elston 1992b). For instance, when variance in food patch return rates are low, the added utility of toolstone at Tosawihi may have balanced food resource opportunities elsewhere. The archaeological record, however, so far has revealed few seasonal indicators. Variance in food patch return is low in winter, when quarriers would need to build substantial structures and hearths as protection from the elements; since neither have been observed at Tosawihi, we conclude that winter forays were infrequent. It also can be argued that lack of surface water after mid-August (assuming past conditions like those of today) probably limited the time people could spend at the quarries in late summer and fall. Too, the availability of important food resources elsewhere makes this an unlikely season for visits to Tosawihi. Spring visits to Tosawihi are suggested by the occurrence of hopper mortars and pestles in sites adjacent known bitterroot patches. In fact, we have observed that water is present and the abundance of food resources greatest in late spring and early summer, when regional variance in food patch productivity also seems minimal. In addition, a spring visit to Tosawihi to retool after a long winter in residence on the Humboldt River would position people advantageously for summer foraging in the range described by Steward (1938) for the ethnographic Tosawihi Shoshone. We conclude, therefore, that the most likely season of use for Tosawihi was late spring and early summer; confirmation awaits data more directly reflecting seasonality.

Direct evidence regarding prehistoric task group organization or mobility patterns is lacking. Nevertheless, if most quarrying occurred during the early spring and late summer, when family groups were likely to be foraging in the vicinity, the chances are good that parties were comprised of families or groups of families beginning their summer foraging round. Of course, this does not preclude the use of the quarries in any other season by specialized task groups.

Maximizing Toolstone Returns

Our previous work did not contradict the general lithic procurement and processing benefit/cost model. Concentrating on sites peripheral to quarrying, however, we relied on pattern recognition to elucidate strategies minimizing the indirect costs of toolstone acquisition. But most of the data, too, were peripheral to calculating direct costs of lithic procurement or to addressing the problem of toolstone rate-maximization.

Nevertheless, analysis revealed strong patterning in the distribution of bifaces and debitage, indicating much toolstone processing prior to transport from the quarry vicinity. Our general benefit/cost model suggested that such processing was likely part of a strategy to minimize risk and transportation costs. As a test of this, we modeled the benefits and costs of processing at the source versus deferred processing after transport. The model, using quantitative and experimental data on costs (time and caloric consumption) of lithic extraction, processing, and transportation, suggests that deferred processing is cost effective only under certain conditions. In preparing experimental data, we monitored return rates for both extraction and processing, showing that, since failure rates do not increase proportionally to processing rates, it probably pays to increase processing rates as much as possible.

At Locality 36, a site of intensive quarrying and processing, we extended the quantitative approach to investigate the role of rate-maximizing strategies in toolstone procurement. The goal of maximizing toolstone return is achieved through strategies that improve rates of extraction and processing, enabling the transportation of the greatest quantity of useful toolstone from the source. But bedrock quarrying is costly; we suggest that a prudent quarrier should seek the most cost efficient means of extracting toolstone, perhaps at the expense of maximizing toolstone quality. Relying on ethnographic analogy and data from experimental quarrying and processing, we estimated the time and energy requirements for a number of activities, including excavating quarry pits in various soils and bedrocks, extracting toolstone, and processing toolstone packages of different types and transporting them; we also considered failure and discard rates at different points along the reduction trajectory. Thus we are reasonably confident in framing models of lithic procurement, processing, and transportation in terms of rate-maximizing strategies. We expect to observe the consequences of such strategies in measurable or estimable attributes of features and artifacts in the archeological record. In particular, we looked at the number, size, and type of quarry features relative to toolstone occurrence and quality, proportions of biface blank types, numbers and proportions of bifaces in various reduction stages, and amounts and proportions of flakes and shatter in debitage.

In addition to quantitative expectations, our models of lithic acquisition also generate relative or qualitative expectations, tested here by statistical pattern recognition. For instance, if rate-maximization in toolstone extraction were a goal, we expect quarrying to have focused on toolstone of a particular range of quality. We expect the stage of processing to vary with distance from place of extraction, but we do not specify a particular distance for a particular stage, this remaining to be discovered empirically.

Estimating Benefit/Cost Factors of Toolstone Extraction

Extraction is the process whereby quarriers procure toolstone packages that subsequently are transformed into useful tools; it occurs after a decision has been made to work in a particular context, after prospecting, and it precedes toolstone processing. Since venture risk (the probability of losing time and effort invested in procurement) is at its peak during extraction (cf. Elston 1992c:Figure 11), *strategies* of toolstone extraction should strive toward cost-minimization and rate-maximization. Some factors probably important in keeping extraction costs low and toolstone return rates high include the location of toolstone, the structural features of the bedrock that constrain extraction or make it possible, the slope of opalite beds relative to the surface, the relative quality and the ease of extractability of the toolstone, and the size and form of toolstone packages obtainable.

In order to assess whether extraction at Locality 36 was efficient, we need to determine how each factor mentioned above either constrained or offered opportunities to prehistoric quarriers; we then can generate hypotheses about cost-minimizing/rate-maximizing behaviors that can be tested with archaeological data. To meet these goals we first ascertain where opalite occurs in the locality, since its presence would have determined the placement and development of quarry features. Second, we discuss some structural features of the bedrock that would have inhibited or facilitated toolstone extraction. Third, we explore the relationship between the inclination of bedrock and the methods used in its working. Following this, we consider the relative quality and ease of extraction of opalite across the locality. Finally, we estimate the sizes and the forms of toolstone packages that were taken from Locality 36.

Variability in the geological position of opalite beds at Locality 36 should influence the cost of extraction in different settings, and thus account for much of the observed variation in methods of working. We expect to see specific extraction methods employed in particular bedrock settings in order to maximize return rates under particular conditions. For example, bedrock more or less parallel to the surface seems most amenable to planing or to the formation of vertical quarry pits; as the angle of inclination becomes greater, however, adits or tunnels are likely to be formed. Quarry feature and bedrock studies undertaken in areas exposed by trenching allow us to assess this.

Given how Tosawihi opalite was formed and subsequently altered by faulting and erosion, it is likely that many structural features of the bedrock either facilitated or inhibited toolstone extraction. For example, fractures and tuff stringers and pockets may have been worked in order to free large, homogeneous blocks from parent material; beds of tuff underlying lenses of opalite may have been quarried in order to isolate ledges of toolstone from which flakes or blocks could be removed. On the other hand, massive opalite may have been so dense that aboriginal technology could not free usable pieces from parent material. Relationships between bedrock features and techniques of quarrying should support this; so we examined fractures and the massiveness of bedrock, as well as tuff bands, pockets, and stringers to determine if different extraction strategies may have been followed given variable geological conditions. Extraction techniques used during actualistic quarrying experiments under varying geological conditions also are discussed in order to evaluate which methods of working may have been most productive.

Determining the relative quality and ease of extraction of toolstone from parent material requires study of the structural features of the bedrock. Differential silicification and the degree to which bedrock is fractured determine toolstone quality. By definition, massive opalite is high quality toolstone because it is homogeneous, while unsilicified tuff or opalite with fractures, vugs, or pockets or stringers of unsilicified tuff, is of lower quality. Nevertheless, such structural features may facilitate extraction by providing means of ingress in to the bedrock, whereas massive opalite may not be quarryable by means available to prehistoric foragers. We suppose that the relative ease of extraction varies directly with the relative quality of toolstone (poor to excellent); moreover, toolstone return *rates* are also likely to vary in relation to toolstone quality. Analysis of bedrock quality and ease of extraction allows us to determine relationships between the two variables, and quantitative data obtained from actualistic quarrying experiments allow us to estimate toolstone return rates across various quality grades.

The size and form of packages extracted from bedrock impose limits on the morphology and dimensions of tools that can be produced, as well as on the techniques used to produce them (Jones 1984; cf. below). It is important, therefore, to understand *what* prehistoric quarriers were capable of procuring from parent material. Volumetric estimates obtained from quarry feature studies would offer one venue of investigation, and the sizes and shapes of toolstone packages obtained from actualistic quarrying experiments offer another. Both measures should provide an estimate of minimum and maximum dimensions of toolstone packages, as well as variation in their shape.

Examining Efficiency and Profitability of Toolstone Extraction

If increased return rate was a goal of lithic procurement at Tosawihi, how could be expect to see it played out in the archaeological record? For example, during the initial phases of extraction (e.g., removal of poor quality toolstone from a bedrock outcrop or the excavation of overburden), *where* can we expect quarry working and development to begin, and where should workings proceed thereafter? Once toolstone has been reached, where should extraction be focused if quarriers are to realize the highest rates of return?

The presence or absence of toolstone on the surface (either as clastic materials or outcropping bedrock) must influence the placement and development of quarry features over time; moreover, depth and nature of deposits overlying buried bedrock should influence quarrying behavior. Quarriers first would have pursued stone in those places where toolstone obviously was present and extraction costs were lowest; thereafter, places where costs were higher would have been exploited. Thus we reconstruct where toolstone may have outcropped prior to prehistoric exploitation of Locality 36, and we examine the soils overlying bedrock. Data from actualistic quarrying experiments allow us to estimate rates of excavation in different soils, and radiocarbon dates ordered the sequence of pit placement and development.

Once quarriers reached toolstone-quality bedrock, we suspect that they focused on those areas providing the best extraction returns, even if the highest quality material had to be ignored. We examine data from our actualistic experiments to estimate return rates across different portions of the bedrock and predict where toolstone return rates should have been highest. We drew surface maps of the exposed bedrock and quarry features to determine where toolstone extraction was most intense and if our hypotheses are supported.

Efficiency and Profitability in Toolstone Processing and Tool Production

We have remarked previously on intensification in the use of the Tosawihi Quarries, particularly through the Late Archaic, and speculated on the possibility of increased trade as a driving force. In addition to intensification of bedrock quarrying, what other indications of toolstone production for trade might we look for? Torrence (1986, 1989) suggests that when demand for lithic products is great enough (as in a market economy), producers are more likely to employ such strategies of processing and tool production, as use of standardized products, specialist quarriers or knappers, simplified production procedures, optimized product design, structured use of space, and organized task groups (as noted above, however, we believe these strategies to be rate-maximizing, rather than efficient). Thus, if use of such rate maximizing strategies in toolstone processing and tool production are visible in the archaeological record of Tosawihi, we can consider whether these efforts were beyond what we might reasonably expect of hunters and gatherers producing tools for their own use. If so, we might regard the development of a market for Tosawihi opalite as more likely.

After extraction, the options for processing toolstone are limited by the form of material extracted. Following the logic outlined above, an understanding of prehistoric extraction goals guides our understanding of how toolstone could have been further reduced. Since the production of tools and other transported forms is the goal of lithic procurement, determining *what* was produced and *why* particular technological strategies were followed is important for examining any model of lithic economy.

The high cost of toolstone transport dictates that initial packages be reduced to maximize the amount of *useful* toolstone mass prior to transport. Unfortunately, we cannot determine why a particular form was considered "useful." Rather, we are left to assume that transported forms were, by definition, "useful." For example, bifaces may be transported for use as combined tools and flake cores, simply for use as tools, to serve as cores (Kelly 1988), or even to be traded to someone else. We are forced to rely on evidence of toolstone processing at any given place to determine what such *useful* forms were. Obviously, the usefulness of a tool form may vary depending on many factors. For example, in our earlier research we found a fairly consistent pattern of increase in late stage biface frequency at greater distances from toolstone sources

(Bloomer et al. 1992). At greater distance from opalite sources, then, the "useful form" (as evident archaeologically) increases in reduction stage. However, even 12 km away from toolstone sources, such "useful" items had not yet been utilized to do anything. We examine these issues with reference to the archaeological data from Locality 36 and the Tosawihi area as a whole, our replication data derived from quarrying and processing experiments, and from ethnographic data.

Discovering Toolstone Packages

Determining what was produced at Locality 36 requires estimation of several factors. First, the size and form of packages extracted from bedrock must be determined, since these constituted parameters on the size and forms of tools as well as the techniques used to produce them. Second, the size and form of products must be estimated, as well as the techniques used to bring them about. Third, we seek to estimate what was transported from Locality 36. Finally, since all these factors may have changed through time, we seek also to detect chronological differences among them.

We already have discussed ways to determine the techniques and likely products of toolstone extraction in terms of attributes of opalite occurrence. Analysis of the products derived from extracted blocks also can indicate the initial forms from which tools were fashioned. Thus, we examine the frequency of varieties of biface blanks, the proportional frequency of large debitage (including angular debris), and the incidence of reduction techniques specific to particular reduction strategies. In ensuing chapters, we examine the frequency of attributes indicative of blank form in the biface assemblage, use of specialized biface thinning techniques, debitage size-grade ratios, and debitage type frequencies.

Strategies of Lithic Processing

We looked at strategies of lithic processing through stone tool and debitage studies. We presume that most successful chipped stone reduction sequences terminated when the biface, core, or flake was removed from the site; remnant tools, cores, and flakes are failures and refuse. Bifaces broken in manufacture are one avenue of inquiry into blank forms and lithic reduction techniques (including heat-treatment) used on different blank forms. We examine these in Chapter 5. Debitage from post-extraction processing and reduction retains important data. Comparing Locality 36 debitage samples with experimental control assemblages we can see the range of reduction techniques employed, the dominant reduction stages completed, and the point(s) at which reduction ceased (cf. Chapter 4).

Stone tool and debitage studies are used to estimate the probably successful products of lithic reduction at Locality 36. To do this, we use a simple mathematical model relating observed failure rates to observed biface frequency. Under-represented reduction stages are likely to have been transported; debitage evidence provides an independent examination of the same issue. By examining the frequency of different reduction stages, we can specify whether debitage roughly matches the Locality 36 tool assemblage or shows that some tools are missing. Temporal change in tool production is examined by controlling for time, where possible.

We also address these questions by contrasting Locality 36 with other quarry assemblages from Tosawihi (Elston and Raven 1992). Although no other quarry has been examined as extensively as Locality 36, differences in product form and reduction techniques can provide insight into use of the greater Tosawihi vicinity.

The Structure of Quarrying and Ancillary Activities

Locality 36 is one of the few quarries scrutinized extensively in North America. Scant ethnographic accounts of quarrying emphasize that quarry workers tend to perform particular actions in particular places (e.g., Binford and O'Connell 1984; Jones and White 1988), but these descriptions are difficult to overlay onto archaeological sites, since the archaeological record may represent hundreds or even thousands of individual events like those described ethnographically. This means that seeking individual flint knappers in the pavement of debris at Locality 36 is fruitless. Instead, understanding the spatial organization of the locality requires changing the focus of inquiry from individual events to the aggregate spatial pattern. Where humans can work is determined by the presence of suitable work space; thus we can expect regular spatial patterning at Locality 36 (and many other quarries). These owe to the "messy" nature of quarrying itself. Large blocks of useless tuff, unused opalite, smears and piles of dirt, and other trash, would have made an active quarry pit a poor place to sit and reduce bifaces. Hence, we expect that the incidence of biface reduction at any given moment should be low at or near active quarry features. Abandoned and unused quarry features may present similar, though less hazardous, problems. Large blocks can litter the surfaces of quarry pits and their environs, making them unsuitable work spaces, even though the pits themselves are not in use. So, we further expect that except for extraction, initial assaying, and blank acquisition, most later stage lithic reduction actions *should* occur away from quarry pits. This statement is conditional, however; we examine it in some detail in Chapter 10, where the spatial distributions of features, artifacts, and outcomes of prior analyses are presented and discussed.

We ask, too, if it is possible to discern task group structure from occupational pattern, either generally or at given time periods. We sought evidence of ancillary activities such as food acquisition and preparation, hearth-associated activities, and other non-quarrying tasks. Tools and debitage of exotic material, microwear evidence, flotation analyses, and other studies are brought to bear on the question.

Summary

Locality 36, of many intensively-used quarries at Tosawihi, provides our most direct glimpse into processes of prehistoric toolstone extraction and lithic production in north central Nevada. Employing optimization models that assume prehistoric quarriers were acting to increase their net returns, we evaluate hypotheses about cost-minimizing/rate-maximizing strategies of toolstone procurement and processing. Investigation of site formation processes, examination of geomorphologic characteristics, in-depth technological analyses, actualistic quarrying and replicative studies, and use of economic transport models all will inform the complex system of lithic production witnessed at Tosawihi.

Before sketching the field methods applied at Locality 36 (Chapter 3) and then turning to the technological and theoretical issues outlined above (subsequent chapters), in the next chapter we place Locality 36 and the Tosawihi Quarries in their larger regional, natural, and cultural contexts.

Chapter 2

NATURAL AND CULTURAL SETTING

Kristopher R. Carambelas

The Tosawihi Quarries (26Ek3032) occupy a rocky, gently undulating expanse at the junction of the Sheep Creek Range and the southwestern foothills of the Tuscarora Mountains (Figure 2). Landforms in the area have been moderately dissected by currently seasonal drainages, eroding considerably since their formation. The Tosawihi Quarries encompass elevations between 1675 m and 1860 m amsl, standing some 200 meters above extensive plains to the west and the south, and some 580 meters below the peaks of the Tuscarora Range 19–24 kilometers to the east. The area constitutes a mid-to-upland setting which is transitional between two distinct ecozones, and the biota which it hosts are communities and species that are more dominant in neighboring settings.

Locality 36 lies in the southern reach of the Tosawihi Quarries, one of 225 archaeological localities comprising the site known administratively as 26Ek3032 (Figure 3). The locality occupies a portion of the top and southwestern slope of a northwest-southeast trending ridge at an elevation of 1756 m amsl (Figures 4, 5). Outcrops of silicified lithic material and a complex (n=55) of quarry pits signal a place where superior toolstone was obtained prehistorically (Elston, Raven, and Budy 1987:42).

Geology

Late Miocene or early Pliocene alteration of Tertiary volcanics modified the lithic landscape in the vicinity of the Tosawihi Quarries. Hydrothermally-induced silicification of rhyolitic ashes and tuff left vast beds of a milky, internally homogeneous opalite (Bailey and Phoenix 1944:17-21) that evolved through dehydration and crystallization. Minimal internal structure and relative homogeneity lent the material desirability as toolstone, attracting the attention of prehistoric quarriers; lodes of cinnabar trapped in the upper components likewise attracted the attention of mercury miners early in the 1900s, prompting the initial exploration of the Ivanhoe Mining District (Bailey and Phoenix 1944; Benson 1956; Hollister 1986:4; Smith 1976; Zeier 1987:4-8), an endeavor that continues to the present with gold now the focal point.

Other principal geologic units consist of rhyolite flows dominating the plateaus east of the quarries and massive basalts that outcrop in the red hills to the west. Both materials were transported to Locality 36 by prehistoric quarriers for use as quarrying and reduction tools (cf. Chapter 6).

Water

The Tosawihi Quarries lie entirely within the higher, eastern reaches of the Lahontan hydrographic basin (Mifflin and Wheat 1979:Plate 1); surface waters drain west down the Humboldt River system to their terminal basins in the Humboldt and Carson sinks. Minor tributaries feeding the Humboldt from the flanks of the quarries include perennial streams to the north and west (Willow Creek and Rock Creek, respectively), and to the south (Little Antelope Creek, which flows seasonally). With the exceptions of the seasonal drainages in the gorges of Velvet and Little Antelope Canyons, drainages near the quarries are ephemeral and run-off is rapid.

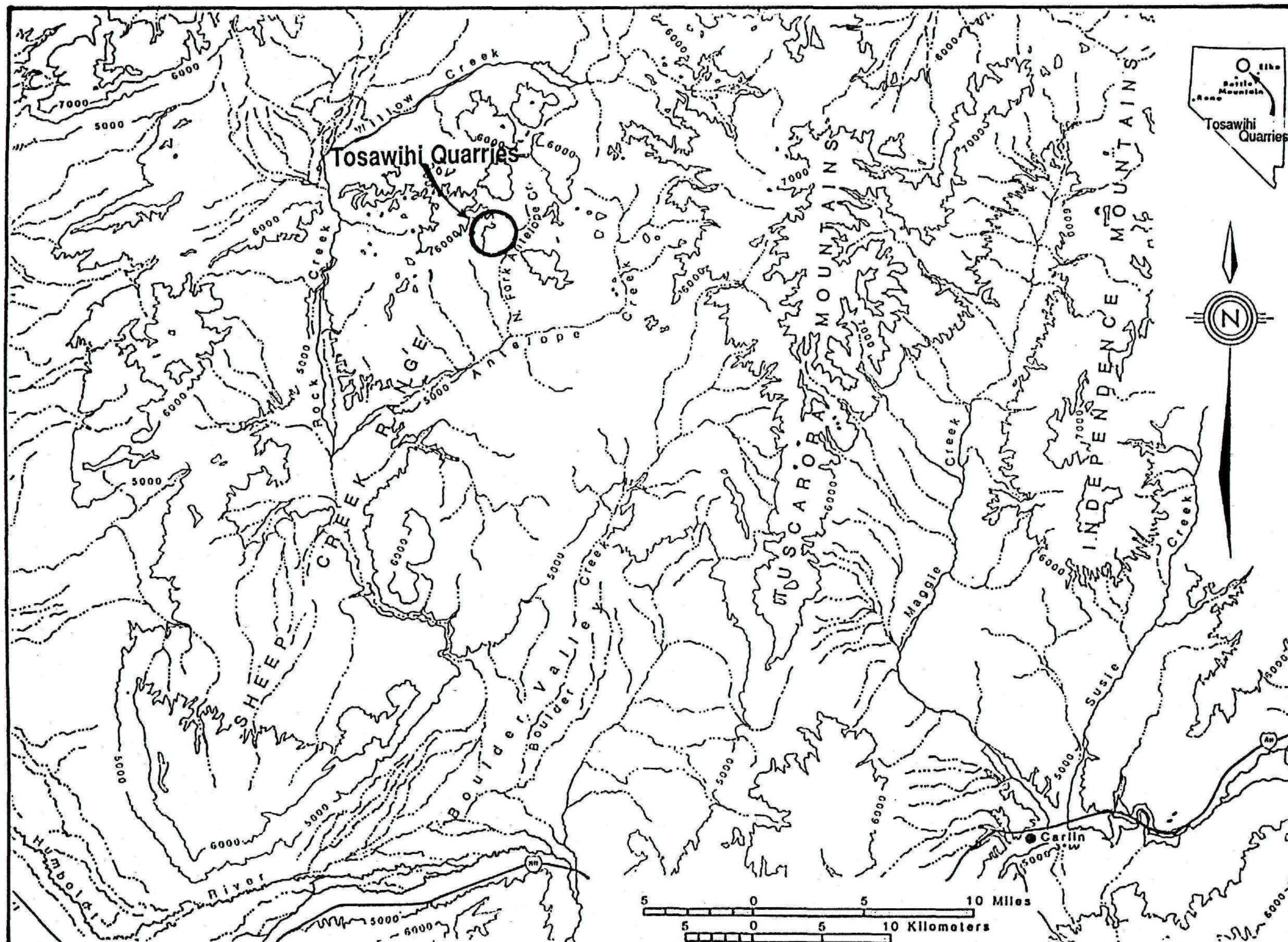


Figure 2. Regional map.

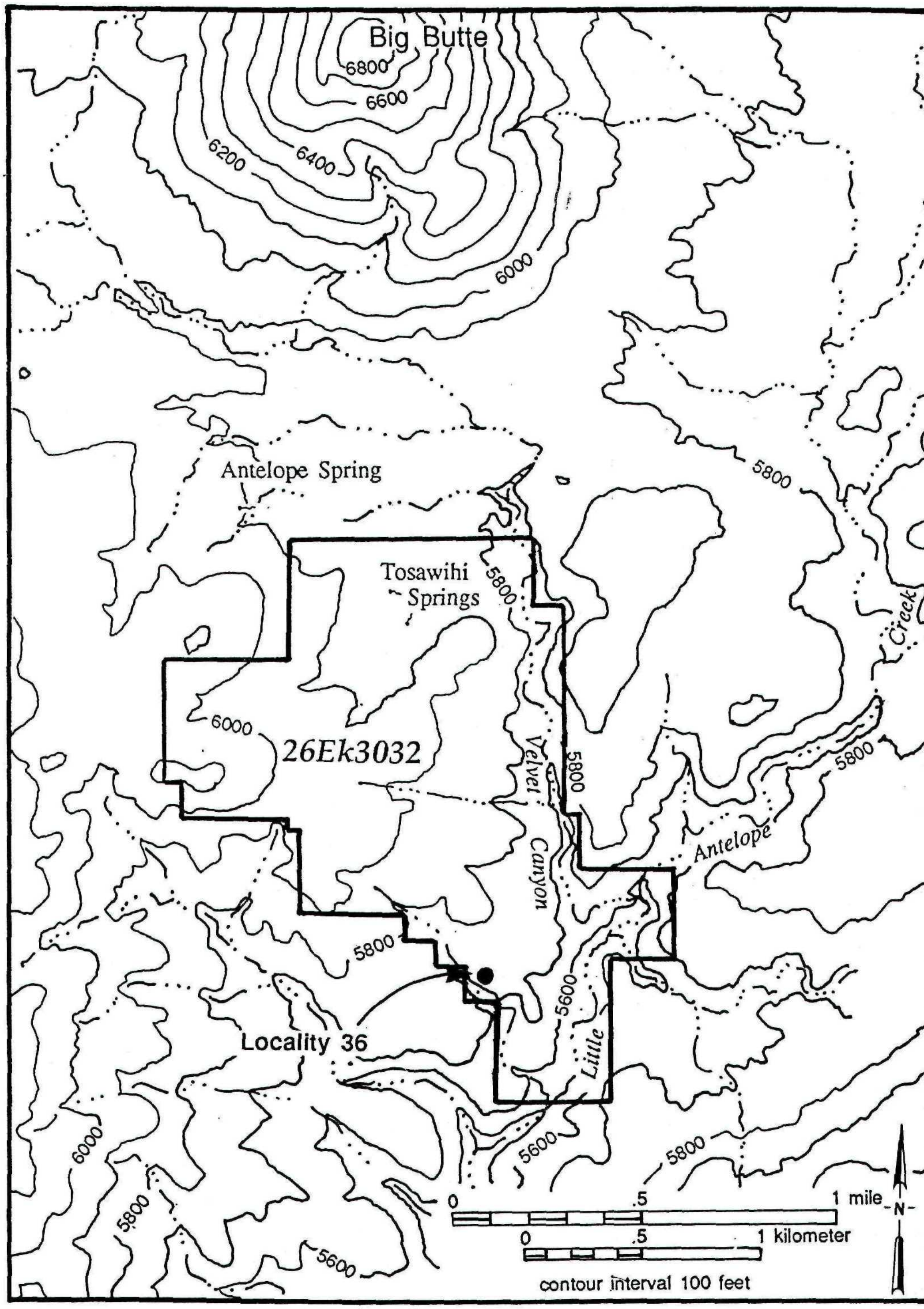


Figure 3. Location of Locality 36 relative to 26Ek3032 site boundaries.

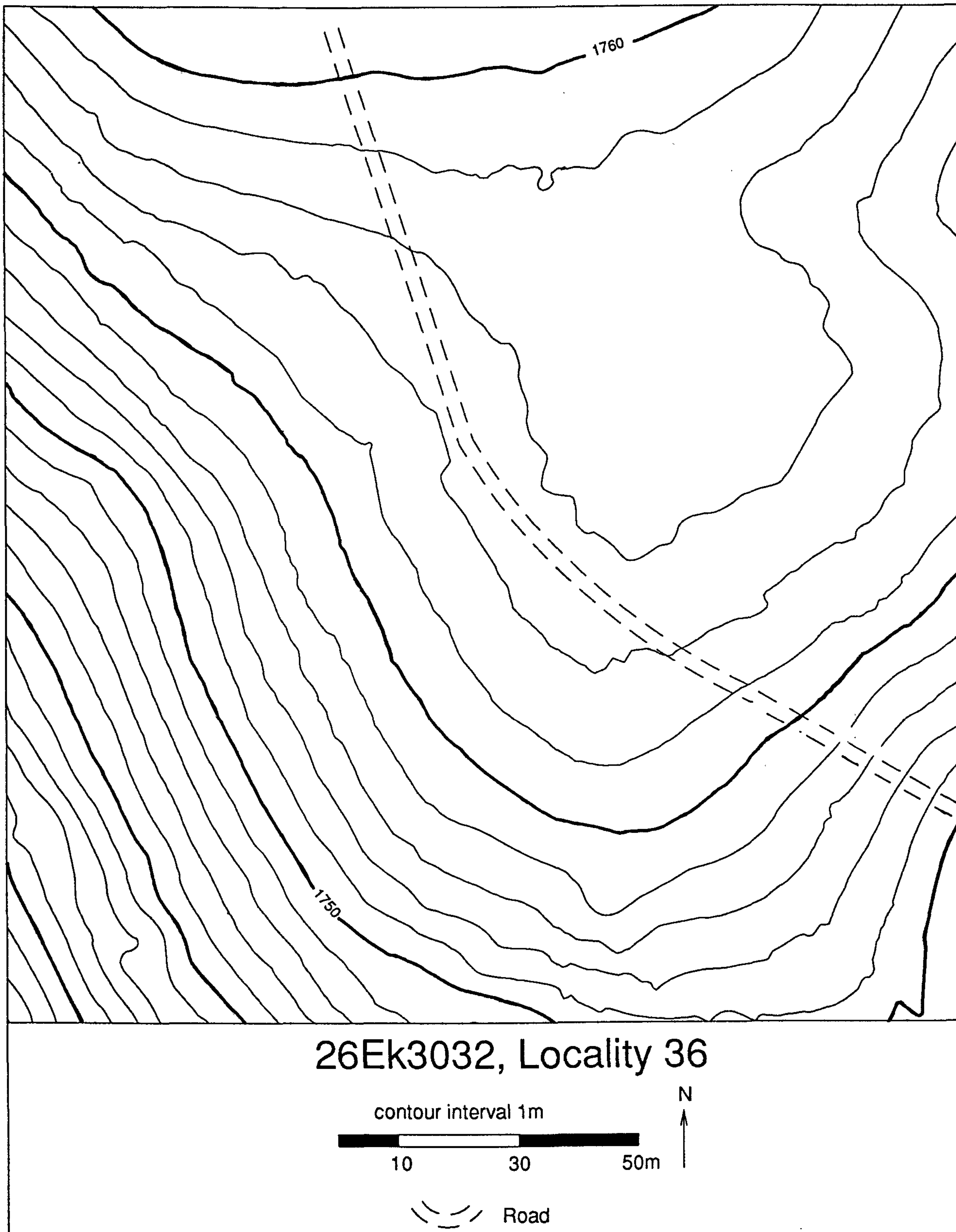


Figure 4. Topographic map of Locality 36.

Figure 5. Locality 36, view of southwest facing slope.

Few springs are generated by the shallow, seasonally depleted aquifers. Ivanhoe and Buttercup Springs to the north of the quarries have yielded water beyond August and, in recent years, have maintained a modest, late-summer flow in Ivanhoe Creek; Tosawihi and Antelope Springs in the main body of the quarries, however, and minor seeps east and west of the quarries, are dry by August. Although various relict spring mounds (chiefly in Big Butte Valley) attest to better water in the past, *access* to water over much of the Holocene almost certainly imposed severe constraints on human exploitation of the quarries (Raven 1992b).

Early in the 1990 and 1991 field seasons (mid May to early June), archaeologists noticed that quarry pits excavated into massive opalite beds at Locality 36 retained water from snow melt and rain showers. Although toolstone probably was the chief attraction at Locality 36, no doubt the gratuitous accumulation of water in opalite reservoirs was an additional benefit to quarriers working at the locality.

Flora and Fauna

Vegetation around Tosawihi is an expression of the Artemisian biotic province, characteristic of the high desert valleys and lower foothills of the northern Great Basin (Billings 1951:110-113; Cronquist, Holmgren, and Reveal 1972). Two communities of this sagebrush-grass zone occupy the area, their incidence conditioned largely by elevation, slope, and aspect. Silty bottom lands and other areas of deeper soils, as well as semi-shadowed northern exposures, are dominated by big sage (*Artemisia tridentata*) and rabbitbrush (*Crysothamnus nauseosus*) in the shrub component, and by Great Basin wildrye (*Elymus cinereus*) and bluebunch wheatgrass (*Agropyron spicatum*) in the grass component. Thin-soiled settings (i.e., knoll-tops, cobble fields, washes) where seasonal drainage continuously has inhibited soil development tend to be occupied by a community composed primarily of low sage (*Artemisia arbuscula*), phlox (*Leptodactylon* sp.), squirreltail (*Sitanion hystrix*), and Idahoe fescue (*Festuca idahoensis*). Numerous forbs are associated with the two communities, including various buckwheats (*Eriogonum* sp.), globe mallow (*Sphaeralcea* sp.), *Mentzelia*, lupine (*Lupinus* sp.), larkspur (*Delphinium nuttallianum*), and bitteroot (*Lewisia* sp.).

Less prevalent plants are found in the microhabitats of the quarry vicinity. Canyon bottoms and heavily shaded northern exposures support stands of wild rose (*Rosa* spp.), gooseberry (*Ribes aureum*), chokecherry (*Prunus virginiana*), and serviceberry (*Amelanchier alnifolia*); *Artemisia ludoviciana*, an annual sage, occupies the dry sandy floors of some of the gorges, brief strings of willow (*Salix* sp.) are found in moist stream channels, and a few barren exposures east of the quarries host unexpected clumps of *Coryphantha vivipara*, a small cushion cactus. Introduced species including sedge (*Carex* sp.) and curley dock (*Rumex crispus*) occur in a few wet meadows; an additional foreigner, cheatgrass (*Bromus tectorum*), has invaded a recently burned area of Big Butte Valley, along with mustard (*Brassica* sp.) and thistle (*Cirsium* sp.).

The Tosawihi Quarries lie within the Upper Sonoran life zone (Merriam 1889), the largest, most diverse life zone in the region. Water is scarce and seasonal at the quarries, however, and vegetation communities there are neither diverse nor particularly productive; consequently, few animals inhabit the vicinity. Larger mammals seasonally attracted to the area include antelope (*Antilocapra americana*) and mule deer (*Odocoileus hemionus*). Elk (*Cervus canadensis*) have been sighted, and their antlers observed, near the quarries. A sheep horn (*Ovis canadensis*) and bison bones (*Bison bison*) recovered from localities of 26Ek3032 suggest these animals have visited the area in the recent past. Smaller mammals are more numerous; over four seasons of archaeological investigation, field crews have observed pocket gopher (*Thomonys* sp.), wood rat (*Neotoma cinerea*), chipmunk (*Tamias* spp.), various ground squirrels (*Spermophilus* spp.), marmot (*Marmota flaviventris*), cottontail rabbit (*Sylvilagus nutallii*), pigmy rabbit (*Sylvilagus idahoensis*), jackrabbit (*Lepus townsendii* and *L. californicus*), bat (order CHIROPTERA), badger (*Taxidea taxus*), kit fox (*Vulpes macrotis*), and coyote (*Canis latrans*).

Observed avifauna include golden eagle (*Aquila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*), kestrel (*Falco sparveius*), great horned owl (*Bubo virginianus*), common raven (*Corvus corax*), turkey vulture (*Cathartes aura*), sage grouse (*Certrocercus urophasianus*), and chukar partridge (*Alectoris chukar*), an introduced species. Field crews also have noted various reptiles: lizards are represented by the western whiptail (*Cnemidophorus tigris*), horned lizard (*Phrynosoma* sp.), and side-blotched lizard (*Uta stansburiana*), ophidians by garter snakes (*Thamnophis elegans*), gopher snakes (*Pituophis melanoleucus*), and western rattlesnakes (*Crotalus viridis*). The only fish observed at Tosawihi, a few dace (*Rhinichthus* sp.), were seen in spring-head ponds and some pools along Little Antelope Creek.

Additional information on fauna of the Tosawihi vicinity are presented by Hall (1946), who discusses mammals, and by Linsdale (1936) and Ryser (1985), who describe birds; fisheries are reviewed by La Rivers (1962), and reptiles are discussed by Stebbins (1966).

Cultural Environment

The study area is situated in the historical Ivanhoe Mining District (Bailey and Phoenix 1944:17-21). Mercury development at the Clementine, Butte, and Velvet workings dates from about 1929, although mercury ore was discovered there in 1911 (Zeier 1987:6). Through the 1940s, mining continued intermittently, with most production generated by the Butte Quicksilver Mine;

with the advent of World War II, mercury mining intensified until 1947 and a brief resurgence occurred between 1957 and 1962, and again in 1966, probably in response to increased international mercury prices (Zeier 1987:6). Exploratory drilling for other mineral resources was initiated in 1979. Gold associated with the local opalite formation and deposits at Red Hill motivates mining ventures in progress today.

Locality 36 occurs in the area used by the ethnographic Tosawihi, or "White Knife," Shoshone, a group who wintered along the Humboldt River near present-day Battle Mountain and whose foraging range included areas flanking Rock Creek (Steward 1938:162). Unlike other Shoshonean groups, whose group names identified prevalent food resources, the name *Tosawihi* is derived from a locally available white toolstone, almost certainly Tosawihi opalite, but references to ethnographic Shoshone (Harris 1940; Powell and Ingalls 1874; Steward 1937, 1938, 1939, 1941) shed little light on the mechanisms of opalite procurement, transport, and trade, or on their relationships to settlement and subsistence.

Previous Research

Early inquiry into the nature and composition of Tosawihi assemblages, distribution of archaeologically transported Tosawihi opalite across the landscape, and chemical "fingerprinting" of the lithic material was made by Mary Rusco in several unpublished papers (Rusco 1976a, 1976b, 1978, 1979, 1983), and attempts have been made to characterize Tosawihi opalite utilizing X-ray fluorescence (Duffé 1976a, 1976b; Raven 1992b). Intermountain Research initiated intensive investigations at Tosawihi in 1987; since that time, investigations have included survey, testing, and data recovery.

Survey of the main body of the Tosawihi Quarries is reported by Elston, Raven, and Budy (1987), while surveys undertaken adjacent the quarries are reported by Budy (1988) for the Western Periphery, by Raven (1988) for the Eastern Periphery, and by Drews (1988) for the Northern Corridor. Historic sites in the Tosawihi vicinity are reported by Zeier (1987). Following these studies, Elston (1988) drafted *A Theoretical Approach to the Archaeology of the Tosawihi Quarries* to guide subsequent inquiry at Tosawihi, and Intermountain Research (1987) drafted a management plan for the quarries. Sixty-five sites peripheral to the heart of the quarries were tested in 1988 (Elston 1989), and, as a consequence, a detailed data recovery program was proposed (Intermountain Research 1988a-d) and executed in 1989 (Elston and Raven 1992).

The 1989 data recovery program demonstrated that, prehistorically, Tosawihi was a place visited primarily for its opalite, and that tools had been manufactured from its raw material sources for at least 8,000 years. Almost all the sites investigated in 1989 were camps or workshops, places to which toolstone or partially reduced bifaces were transported and reduced prior to their export from the Tosawihi vicinity (cf. Chapter 1). Information provided by 1989 investigations, along with information obtained from a recent probabilistic sample survey in the Tosawihi hinterlands (Leach and Botkin 1992), provides important insights into the lithic production system operative in the Tosawihi vicinity.

The present report is concerned with data recovery conducted in 1990 at Locality 36. Unlike previous investigations, which focused on sites peripheral to the main body of the quarries, investigations at Locality 36 are concerned, for the first time, with a quarry site *within* the heart of Tosawihi.

Cultural Chronology

Syntheses of regional cultural chronology have been offered at various levels of abstraction by James (1981), Rusco (1982), Smith et. al (1983), and Elston (1986a), while Elston and Drews (1992) have outlined the cultural chronology for the Tosawihi Quarries. The reader is referred to Raven (1992b) for a comprehensive review of the ethnographic and the archaeological literature relevant to Tosawihi. Below, a comparison of regional cultural sequences is offered (Figure 6) and a cultural chronology proposed for the upper Humboldt region (Elston and Budy 1990) is summarized.

Dry Gulch Phase (?-6000 B.C.). Regarded as Pre-Archaic in the broader sequence of Great Basin adaptations (Elston 1982), this phase originally was defined as the Western Pluvial Lakes *Tradition, assumed to be a lacustrine adaptation (Bedwell 1973). Presently, however, it is* observed in both riparian and upland settings. As the earliest phase recognized along the upper Humboldt, it reflects a distinctive lithic technology, a lack of seed grinding implements, and high residential mobility. Diagnostic artifacts include concave-base projectile points, Great Basin Stemmed points, flaked stone crescents, heavy core tools, scrapers, and choppers; some of these have been noted and recovered at Tosawihi (Elston, Raven, and Budy 1987).

No Name Phase (5000-2500 B.C.). The emergence of Early Archaic adaptation along the upper Humboldt River drainage is marked by Northern Side-notched and Humboldt Series projectile points (Heizer and Hester 1973; Thomas 1981, 1983), but few such sites have been observed (Elston and Budy 1990). Elsewhere in the Great Basin, Early Archaic adaptations represent a probable increase in diet breadth (including the intensification of seed use), increased locational diversity in land-use patterns, and logistical structuring of subsistence pursuits (Elston and Budy 1990).

South Fork Phase (2500-850 B.C.). The Middle Archaic on the upper Humboldt is not well characterized by existing data; Humboldt and Gatecliff Series projectile points, however, are considered diagnostic (Elston and Budy 1990).

James Creek Phase (850 B.C.-A.D. 700). Marking the full expression of Archaic adaptations, this phase witnessed the exploitation of an extremely wide range of settings and resources, broadening of the prey-base, and more eclectic use of the environment. Elko Series projectile points are its primary temporally diagnostic artifacts.

Maggie Creek Phase (A.D. 700-1300). Rosegate Series projectile points (and Fremont Grayware ceramics in the eastern Great Basin) are diagnostic of this phase. At James Creek Shelter, the phase is characterized by further intensification of plant use, increased pursuit of small game, and introduction of the bow and arrow (Elston and Budy 1990).

Eagle Rock Phase (A.D. 1300 to protohistoric times). This phase apparently represents the archaeological record of the Numic peoples who occupied the area at historic contact. Along the upper Humboldt, time diagnostic artifacts marking the phase include Desert Side-notched and Cottonwood projectile points and Shoshone Brownware ceramics (Elston and Budy 1990).

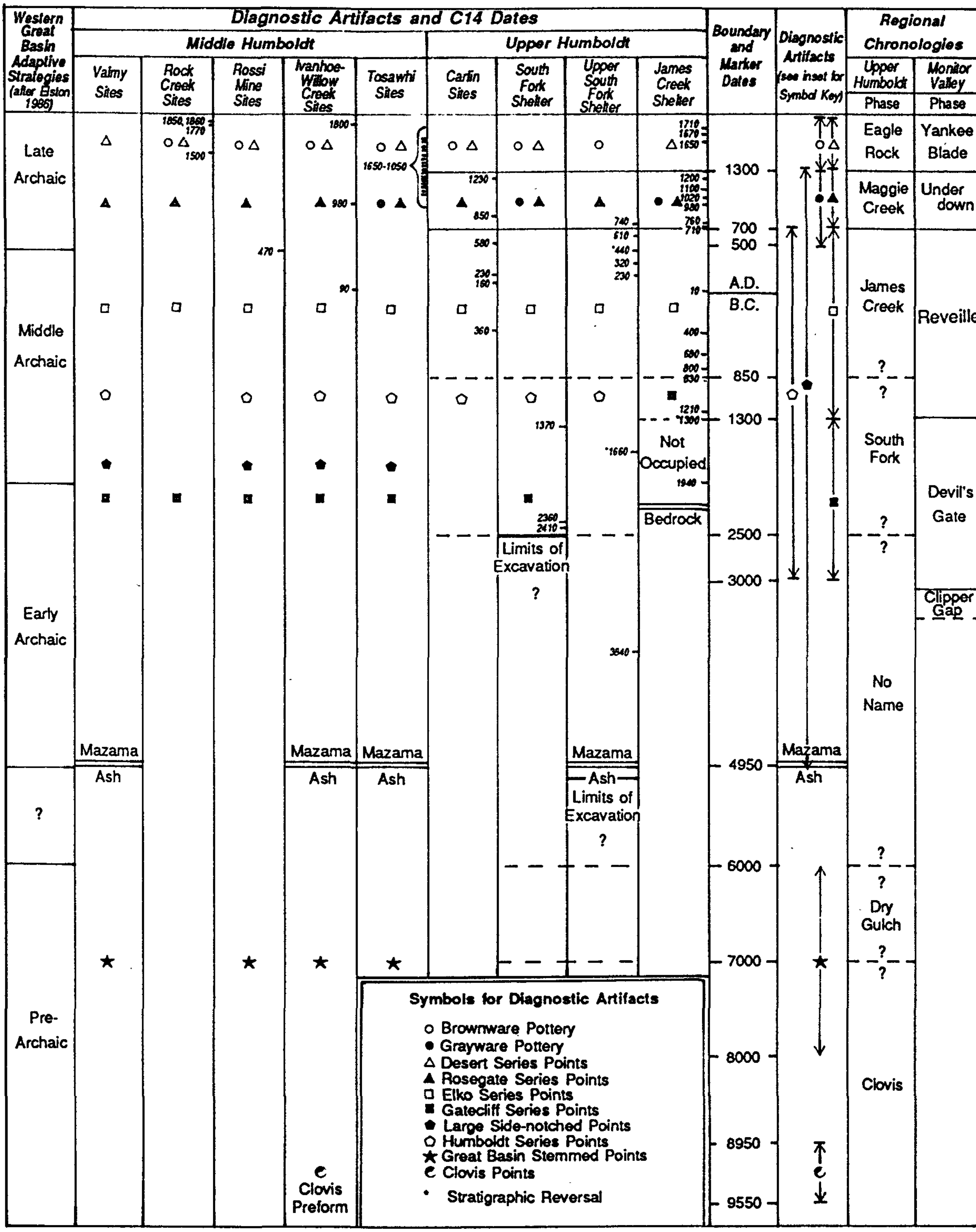


Figure 6. Prehistoric Chronology for the Upper Humboldt Valley, Nevada (after Elston and Drews 1992:Figure 208).

Chapter 3

FIELD METHODS

Dave N. Schmitt, Kathryn Ataman, Kristopher R. Carambelas, Eric E. Ingbar, Melinda Leach, and C. Lynn Rogers

Locality 36 encompasses approximately 5 acres of a ridgetop and west-southwest slope (Figure 7) in the southwest corner of 26Ek3032. Opalite eroding from tuff deposits or occurring within 1.75 m of the surface attracted prehistoric quarriers at least as early as 4000 B.P. The site is covered with a dense blanket of debitage and is pocked with more than fifty depressions produced by prehistoric opalite quarrying. The utilized opalite deposits occur in a 30m wide band that parallels the ridge line 10-30 m below the summit of the ridge. The quarry pits are concentrated in this band, and other, less dense, lithic scatters can be seen in level areas on the hilltop.

Quarry sites often are complex, encompassing large areas, containing concealed but extensive subsurface features, and having voluminous material records. With this in mind, and in light of questions posed by our research design (cf. Chapter 1), diverse field strategies were devised to effect data recovery at Locality 36; these included surface collections, surface scrapes, controlled subsurface excavations, excavation of backhoe trenches, detailed stratigraphic documentation, actualistic quarrying and replication experiments, and in-field debitage analysis. Because the site is so large and so thickly mantled with debitage, sampling was critical to each component of fieldwork; we applied a variety of systematic and judgmental sampling techniques in feature and non-feature contexts.

The Feature Assemblage

Five types of feature were distinguished: quarry pits, reduction features, utilized outcrops, hearths, and possible hearths. Quarry pits were distinguishable in the field as circular to oval depressions; often, but not always, cobble-sized blocks of opalite are associated with them, and debitage almost always is common in and around them. Reduction features, or lithic scatters, are distinct concentrations of debitage not associated with quarry pits. Utilized outcrops consist of opalite exposures that have been battered, flaked, or otherwise manipulated by human action; the five outcrop features observed each consist of the bedrock and an associated lithic scatter. While quarry pits, reduction features, and utilized outcrops were distinguishable on the surface, subsurface quarry pits were discovered during backhoe trenching, and hearths were found only below surface after the central portion of the site had been scraped mechanically. Hearths appeared as ashy, dark, concentrations. Possible hearths also were ashy, and darker than the surrounding matrix, but they were more amorphous and less distinct in color and texture.

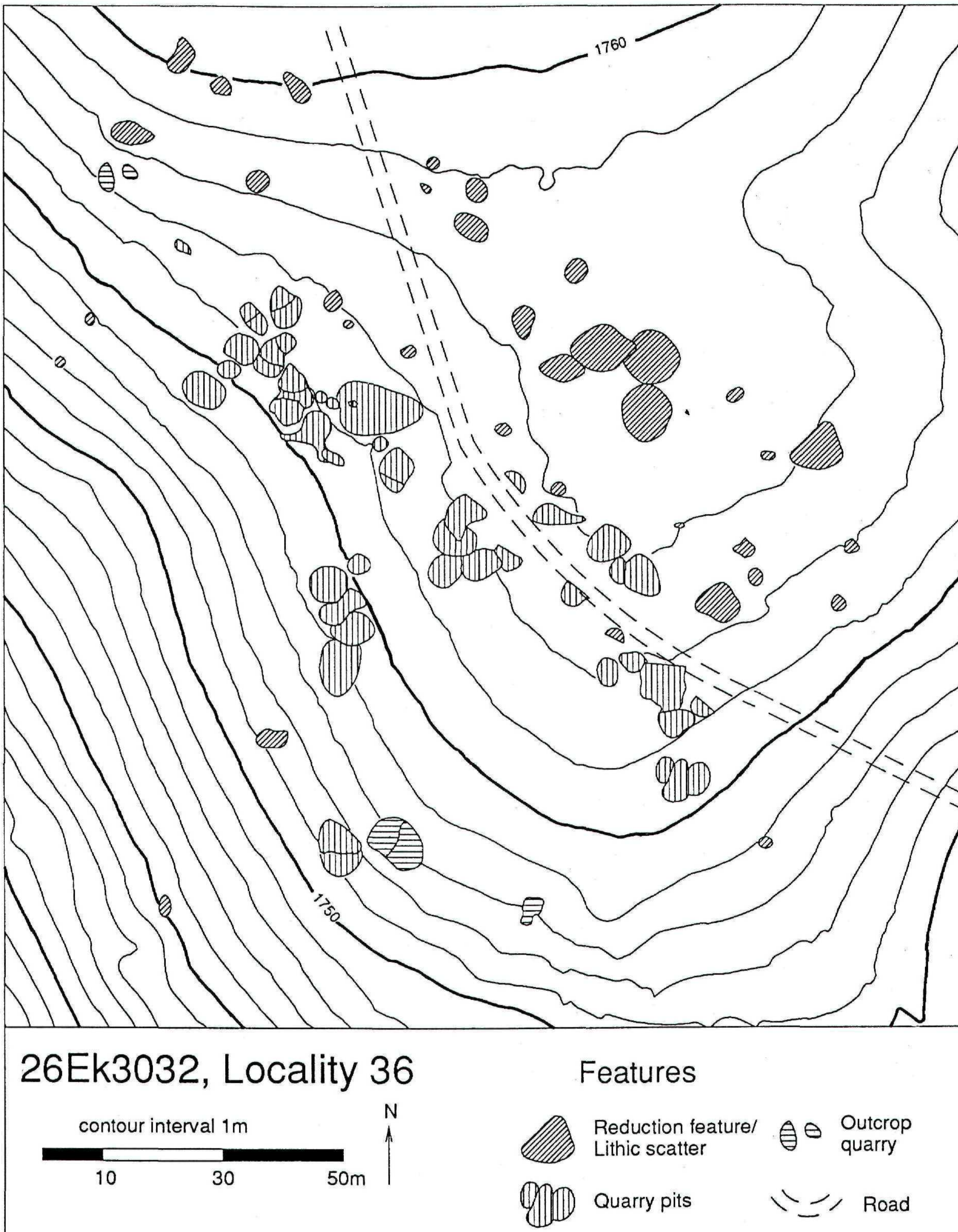


Figure 7. Distribution of features.

Locality 36 contains 108 features. Ninety-seven are surface features, identified by closely spaced transects examined across the site. Five subsurface features were found during backhoe trenching in and around surface quarry pits; all are products of opalite extraction. The other six features were observed during the scraping of approximately 10 cm of the surface mantle from the central portion of the site with a mechanized grader. Five are hearths, the sixth, a possible hearth.

Feature types assigned in the field encompass variation within each type. For example, backhoe trenching of two quarry pits revealed that they also contained adits. Hand and mechanical excavations increased our knowledge of variation within each type. Subsurface examination forced reconsideration of feature type in only one case (Feature 70, a reduction feature adjacent a buried quarry pit).

Our discussions of Locality 36 features rely on the term *debitage aprons*. Debitage aprons are concentrations of chipped stone debris coterminous with the boundaries of most quarry pits at the locality. They are features in their own right, consisting of complex pastiches of formerly discrete reduction features, debris from quarry pits, and things moved downslope by natural processes. The areal extent of debitage aprons precludes their investigation by traditional methods.

Feature type attributes are presented in Table 1, and are summarized below.

Quarry pits—Fifty-five quarry pits appear as surface depressions (Figure 8), often, but not always, filled with rubble (Figure 9). Their depths are variable (cf. Chapter 9). Many, but not all, quarry pits consist of three component areas: pit floor, pit walls, and a berm of debris surrounding the outside of the pit (Figure 10). At Locality 36, quarry pits range in surface area from 2.5 m^2 to a maximum of approximately 88 m^2; over half occupy between 15 and 30 square meters (Figure 11). Five quarry pits were discovered by backhoe trench excavation.

Reduction features—Thirty-seven reduction features were defined in the field as spatially discrete concentrations of chipped stone debitage (Figure 12). Estimates of the number of flakes present on the surfaces of such features range from approximately 100 to more than 2000. At Locality 36, reduction features range in area from 0.1 m^2 to 74 m^2. Reduction features usually are small, encompassing less than a square meter (Figure 13).

Outcrop/reduction features—Five features were defined as lithic scatters associated with opalite outcrops. Examination of the outcrops revealed relatively poor quality opalite, and we infer that little useful toolstone was derived from them. Lithic scatters associated with the outcrops are low in overall density and cover 10 to 40 square meters.

Hearths and possible hearths—These features were encountered after the surface of the ridgetop at Locality 36 had been scraped mechanically. Five hearths (Features 105 to 109; Figure 14) appeared as ashy, dark stains 0.5 to 1.0 m in diameter. Charcoal fragments were present in all, and all but one contained fragments of fire-cracked rock. The hearths were shallow (approximately 10 cm in depth) and lacked prepared collars or edges (Figure 15); perhaps the surface into which they were excavated was removed by the grading. The one possible hearth observed (Feature 110), also exposed by mechanized scraping, was a poorly defined stain, somewhat darker than the surrounding matrix, lacking artifacts.

Table 1. Surface Features.

Feature	Type	Area	Northing	Easting	Investigation Method										
					I	N	T	L	C	S	E	D	F	M	Profile
1	RE	22.9	149.12	21.16	+										
2	OC	19.6	142.15	20.88		+	+								
3	OC	10.5	141.92	17.29		+									
4	RE	3.1	117.73	14.36		+									
5	RE	3.1	110.60	9.46		+									
6	RE	21.6	161.77	29.99	+					+	+				
7	RE	6.6	157.19	35.66		+									
8	BZ	0.0	140.89	24.78											
9	QP	4.9	130.14	30.16	+										
10	BZ	0.0	125.97	27.22											
11	QP	9.4	109.47	37.78	+		+								+
12	QP	24.7	113.68	40.36	+		+								+
13	QP	40.8	105.94	33.48	+		+								+
14	RE	6.3	20.08	26.83		+									
15	QP	24.7	29.80	55.40	+										
16	QP	30.2	31.79	54.75	+										
17	RE	11.8	48.14	44.13		+									
18	QP	30.6	73.05	53.74	+										
19	QP	22.8	99.15	51.45	+										
20	CB	9.6	95.76	53.42	+										
21	QP	27.5	102.35	47.81	+										
22	QP	12.6	104.18	54.41	+		+	+	+						+
23	QP	12.3	105.56	47.92	+										
24	QP	13.7	107.75	48.35	+										
25	QP	13.4	107.38	53.51	+		+	+	+						+
26	QP	11.8	110.12	43.39	+										
27	QP	28.3	111.44	50.29	+		+	+	+						+
28	QP	31.8	112.53	44.75	+										
29	QP	12.4	114.42	48.01	+		+		+						+
30	QP	12.6	117.33	42.34	+										
31	QP	13.9	119.19	46.32	+		+		+						+
32	QP	17.6	121.16	45.70	+		+	+	+						+
33	QP	11.0	119.68	40.77	+										
34	QP	8.3	123.16	41.27	+										
35	QP	5.6	124.10	44.61	+		+		+						+
36	RE	12.2	140.84	42.58	+										
37	RE	7.1	156.40	48.94		+									
38	RE	.6	102.22	113.71						+	+				
39	RE	.9	143.88	71.40		+									
40	RE	2.8	117.51	57.87	+										
41	RE	4.8	112.70	67.73	+										
42	QP	88.0	102.24	62.73	+		+	+	+						+
43	QP	6.5	97.05	57.84	+										
44	QP	17.7	95.20	60.09	+										
45	QP	3.1	97.90	61.80	+										
46	QP	11.0	93.71	65.49		+									
47	QP	11.0	76.83	58.80		+									
48	QP	40.8	70.31	57.60	+										
49	QP	35.3	66.34	58.34	+		+	+	+						+
50	QP	53.0	59.51	55.08	+										
51	RO	42.4	30.69	66.11	+										
52	RO	34.5	31.98	63.53	+										
53	BZ	0.0	7.00	78.20											
54	QP	28.3	75.70	73.60											
55	QP	10.3	78.04	78.90											
56	QP	47.1	81.70	75.09											
57	QP	15.7	77.84	84.43		+									
58	QP	44.2	84.73	76.88	+										
59	QP	11.0	90.96	84.96	+										
60	RE	4.7	99.59	83.36		+									

Table 1, continued.

Feature	Type	Area	Northing	Easting	Investigation Method										
					I	N	T	L	C	S	E	D	F	M	Profile
61	RE	18.9	118.47	86.49		+									
62	RE	4.7	134.57	76.22		+									
63	RE	11.0	139.30	78.57	+					+	+				
64	RE	1.7	193.24	70.87		+									
65	RE	3.1	125.91	95.24	+										
66	RE	72.3	112.99	99.13		+									
67	RE	73.9	110.34	107.13	+										
68	RE	27.1	109.71	93.42		+									
69	RE	58.5	103.42	106.63	+										
70	RE	4.0	89.49	92.13						+	+				
71	QP	35.3	80.00	100.00	+		+	+	+						+
72	QP	30.6	74.20	106.05	+		+	+	+						+
73	QP	10.6	74.94	102.47	+		+								+
74	QP	15.9	72.00	95.00	+										
75	QP	15.7	59.40	100.48		+									
76	RO	11.8	19.58	87.55		+									
78	QP	17.3	40.51	114.80	+										
79	QP	5.9	41.08	112.34	+										
80	QP	8.8	41.63	110.41	+										
81	QP	31.8	55.02	109.41	+										
82	QP	23.6	50.83	112.24	+										
83	QP	12.6	53.64	116.05	+										
84	RE	4.7	75.00	125.00	+					+	+				
85	RE	1.6	83.30	112.87	+										
86	RE	44.0	79.60	123.18	+					+	+				
87	RE	13.0	95.20	126.59						+	+				
88	RE	4.7	105.10	121.58		+									
89	RE	7.1	90.34	176.14		+									
90	RE	56.6	94.94	136.34		+									
91	RE	.1				+									
92	RE	28.3	79.86	141.07		+									
93	RE	5.9	69.93	138.64		+									
94	QP	31.4	84.38	90.84	+										
95	RE	4.1	30.56	126.70		+									
96	QP	6.4	64.88	101.94	+										
97	QP	14.5	61.00	106.00	+										
98	RE	8.8	120.89	55.19		+									
99	QP	22.4	97.13	68.14		+									
100	QP	2.4	104.23	57.78	+										
101	RE	44.0	69.85	119.71	+										
102	QP						+	+			+				+
103	QP						+	+							+
104	QP						+								+
105	HT										+				
106	HT										+				
107	HT										+				
108	HP										+				
109	HT										+				
110	HP										+				
111	QP							+							+
112	QP														+

KEY:

Feature Type
- QP = quarry pit
- RE = reduction feature (lithic scatter)
- OC = outcrop quarry
- CB = cobble quarry
- RO = reduction/outcrop quarry
- HT = hearth
- HP = possible hearth
- BZ = bulldozer cut

Investigation Method
- I = inventory collections
- N = feature inventory without collections
- T = backhoe trench
- L = lithic inventory column sample(s)
- C = cruciform collections
- S = surface scrapes
- E = excavation units
- D = discretionary (systematic random) surface scrapes
- F = extra-feature surface collections (isolates)
- M = miscellaneous (uncontrolled) collection

Figure 8. 26Ek3032, Locality 36, Feature 72, quarry pit.

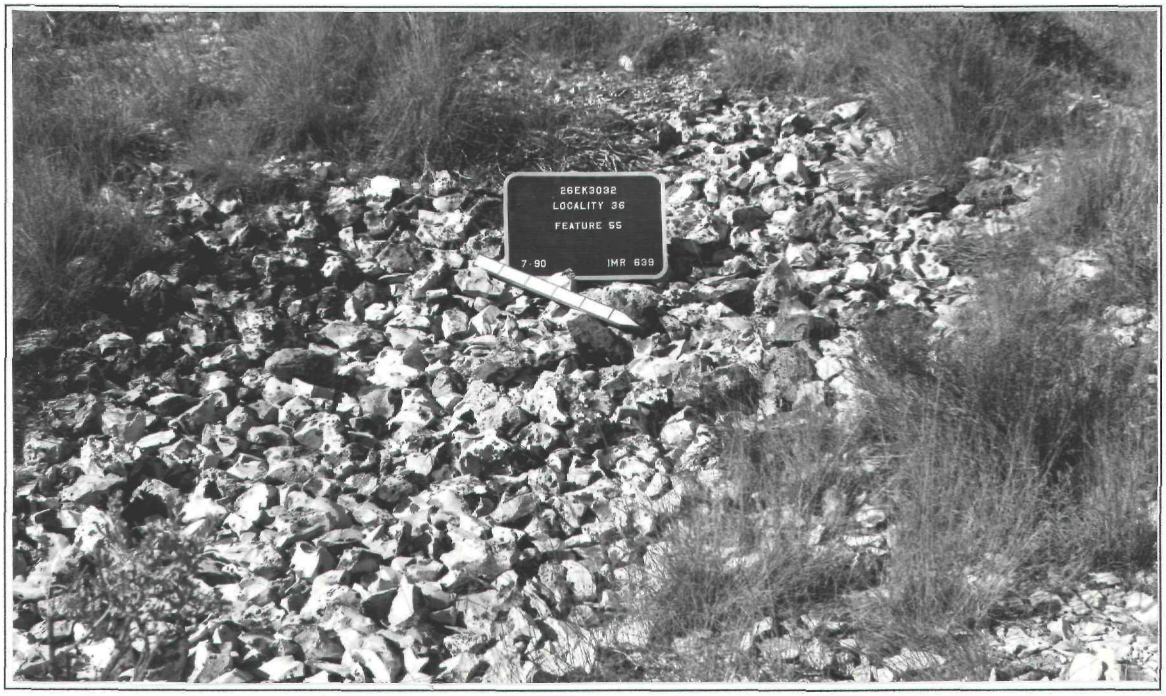


Figure 9. 26Ek3032, Locality 36, Feature 55, quarry pit.

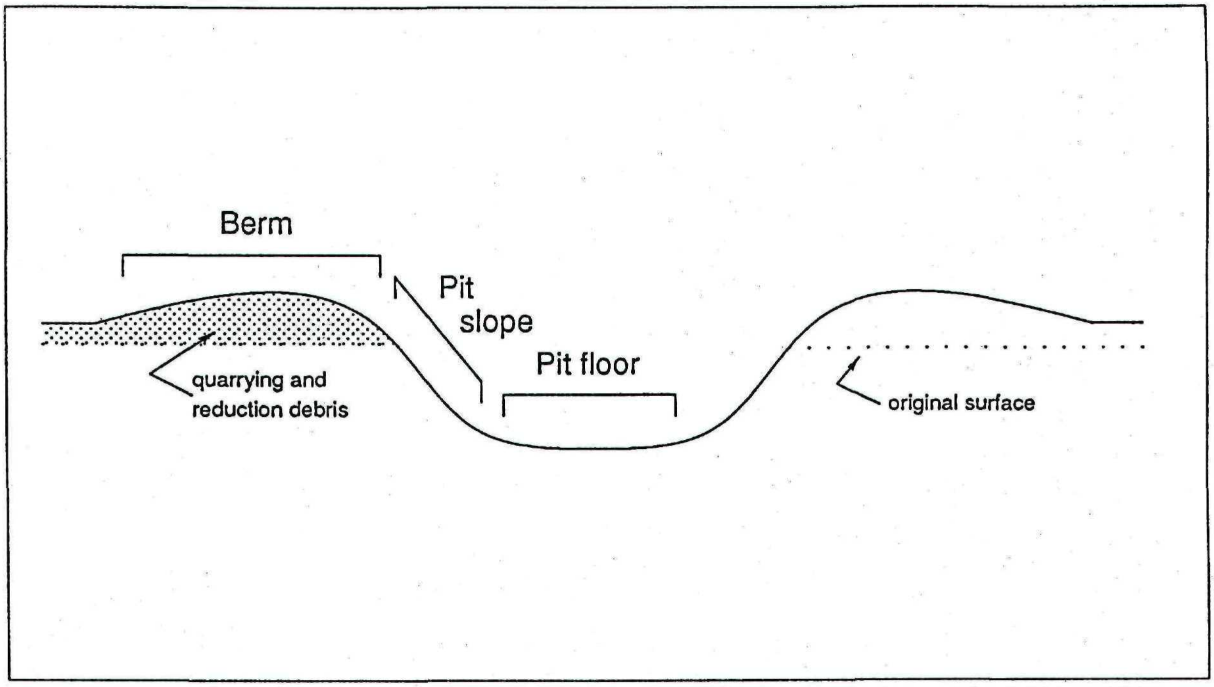


Figure 10. Schematic profile of a quarry pit.

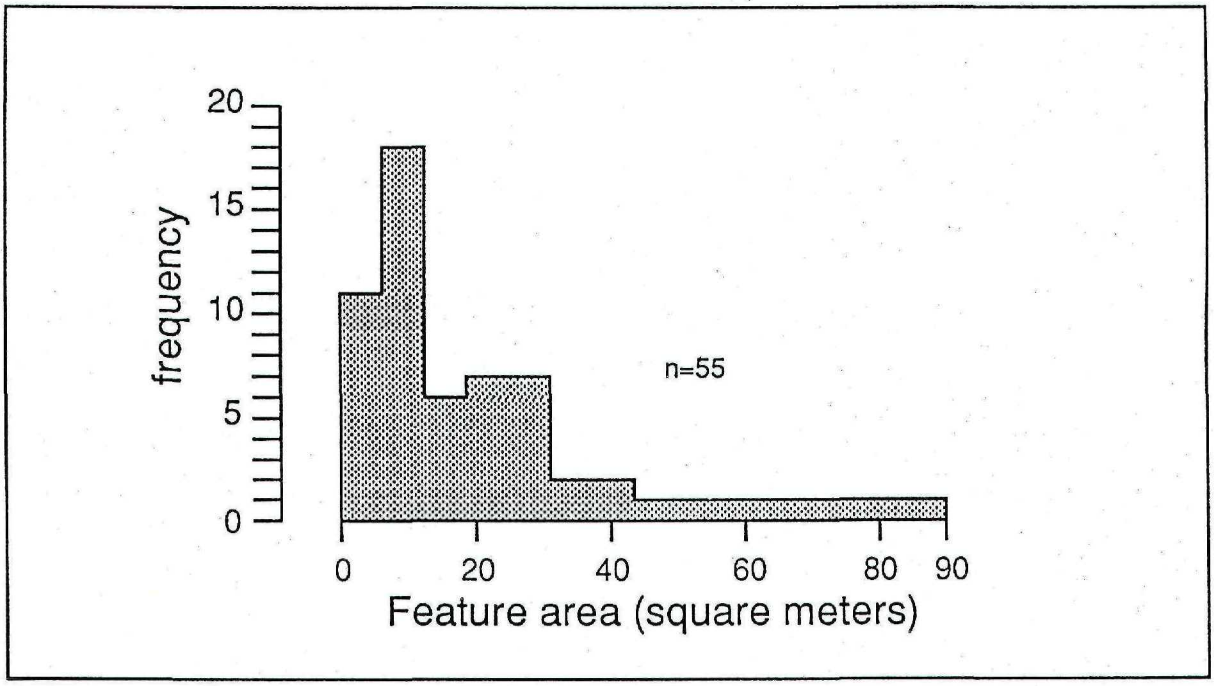


Figure 11. Histogram of quarry pit surface area.

Figure 12. 26Ek3032, Locality 36, Feature 60, reduction feature/lithic scatter.

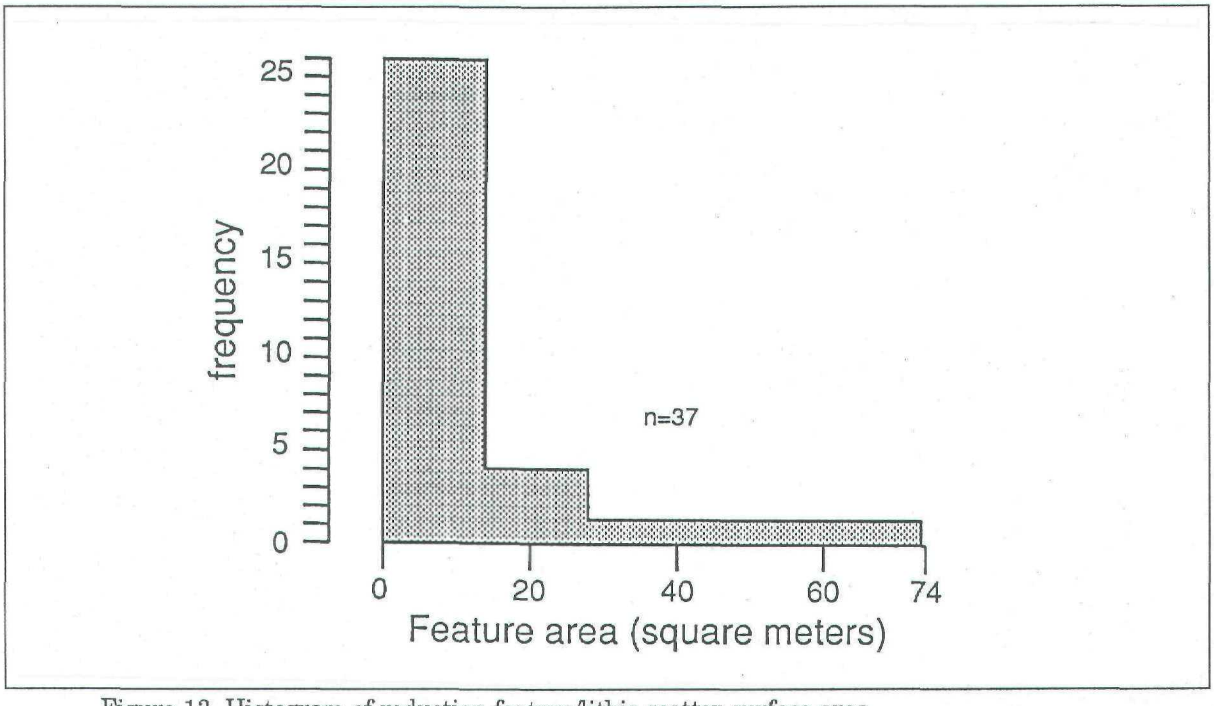


Figure 13. Histogram of reduction feature/lithic scatter surface area.

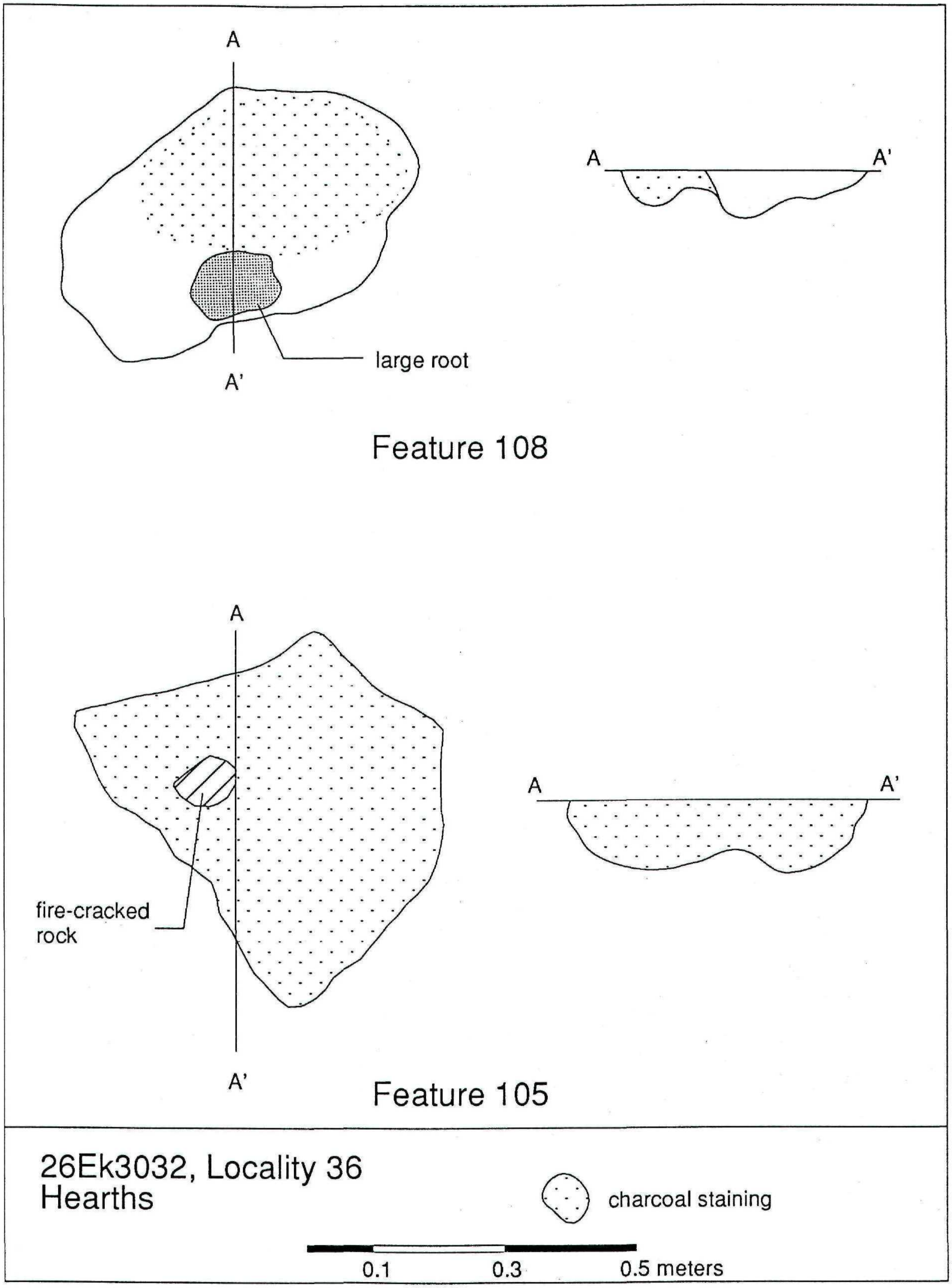


Figure 14. Plan views and profiles of hearths.

Figure 15. 26Ek3032, Locality 36, Feature 107, buried hearth.

Quarry pits dominate the surface feature assemblage (Table 2). Reduction features are less frequent, and outcrop/lithic scatter features are relatively rare.

Table 2. Frequencies of Surface Feature Types.

Feature Type	n	%
Utilized Outcrop	5	5.2
Quarry Pit	55	56.7
Reduction/Lithic scatter	37	38.1
Total	97	100.0

Surface Collection, Feature Inventory, and Random Surface Scrape Excavation

To clarify site boundaries, identify the number and nature of surface features, and investigate site formation processes, initial scrutiny of Locality 36 involved intensive surface survey (2 m transect intervals), during which all features and extra-feature artifacts were flagged for mapping and collection. We then returned to features and documented their size, form, content, and inferred function, and placed a central datum in each for subsequent mapping; mapping was performed with an electronic distance measuring device that recorded data into a computer. Sixty quarry features and 37 reduction features were mapped and inventoried (cf. Figure 7). Formed artifacts (*e.g.*, bifaces, cores, and hammerstones) were plotted on a sketch map and/or were shot in by the electronic transit, and then collected.

We established a 10 m x 10 m grid across the site assigning northing and easting coordinates to the southwest corner of each block. This enabled a surface debitage density sampling scheme, intended to measure the intensity of quarry production as well as the areal extent of quarrying activity. Two small (25 cm^2), randomly drawn units were selected within each 10 x 10 m grid square for surface scraping. Using tape measures, the southwest corner of each unit was measured in from the southwest corner of the grid block, plotted on a map, and shovel scraped to a depth of 2 cm; soils were passed through 1/4 in. mesh.

Investigations within quarry pits and quarry pit complexes employed surface scrape excavation units and backhoe trenches. Measuring 25 x 25 cm or 50 x 50 cm, surface scrapes were laid out in cruciform patterns across three groups of quarry pits. The scrape units crossed pit berms, slopes, and bottoms, and extended to the area outside, but adjacent, the pits. Investigations within the Feature 22 quarry pit complex employed 57 disjunct 25 cm x 25 cm cruciform units (one every 50 cm) through Features 22, 25, 27, 29, 31, 32, and 35 (Figure 16). The Feature 42 transect, which intersected the Feature 22 baseline (Figure 17), consisted of sixteen 50 cm x 50 cm units placed at one meter intervals; the larger collection units were used due to the wealth of large flakes and chunks on the surface. Approximately 35 m to the south, a baseline was established at Feature 49 in order to sample within and adjacent a large, deep quarry pit. Here, we employed 18 disjunct 50 cm x 50 cm units following the surface slope along an east-west axis (Figure 18). Collections in the Feature 72 quarry pit complex employed twenty 50 cm x 50 cm surface scrape units placed across Features 71, 72, and 73, and 12 additional 50 cm x 50 cm units placed perpendicular to the initial baseline (intersecting in Feature 72; Figure 19).

The distribution of types and quantities of debitage recovered from these various contexts in and around quarry pits was expected to address prehistoric task organization. These cruciform-patterned units also provided data to assess the extent of post-depositional surface movement which may have redistributed surface artifacts. The material was screened through 1/4 in. mesh, and angular debris, tuff fragments, and flakes were collected.

Subsurface Excavation

Trenching

Backhoe trenches were excavated first over or adjacent surface scrapes (Figure 20). Extensive use of backhoe trenches (265 m of trench were excavated) was essential to the project, allowing us to investigate prehistoric quarrying strategies, assess variation in toolstone quality, and detect subsurface features. Trenches also were intended to provide data on techniques and strategies of toolstone extraction used by prehistoric quarriers.

Trenching through the Feature 22 quarry pit complex (Trench 4) found the surface pits to be shallow, but revealed a subsurface quarry pit (Feature 112) buried beneath the berm of Feature 27. Backhoe excavations along the Feature 42 transect (Trench 5) found the pit to be deep and rich in charcoal. A large, deep adit and a buried quarry pit (Feature 102) were revealed in the sidewalls of Trench 3, several meters downslope from surface Feature 490. Trenching through the Feature 72 complex (Trenches 1, 2, and 7, respectively) exposed three additional quarry pits (Features 103, 104, and 111).

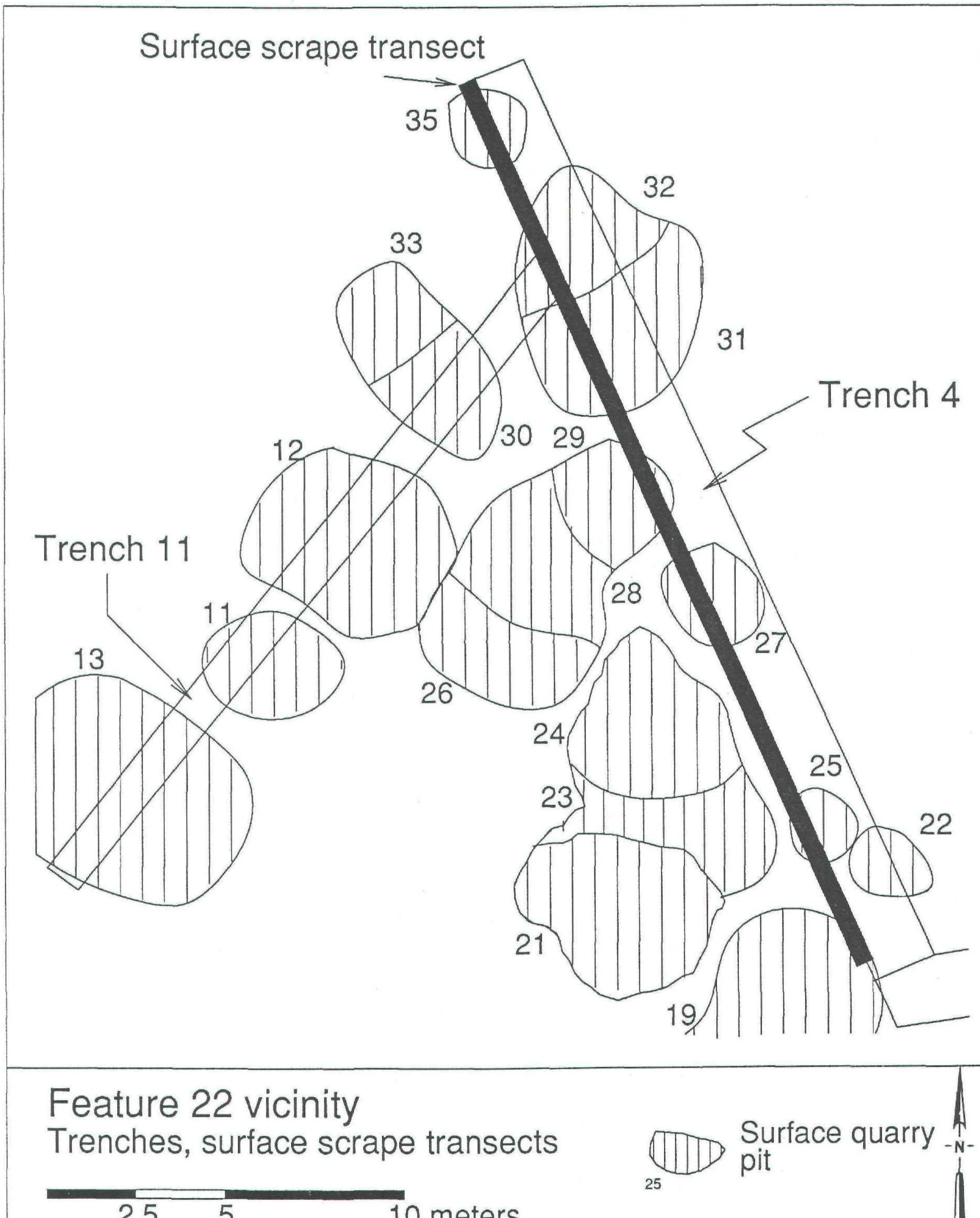


Figure 16. Backhoe trenches, excavation units, and lithic transect collections within the Feature 22 quarry pit complex.

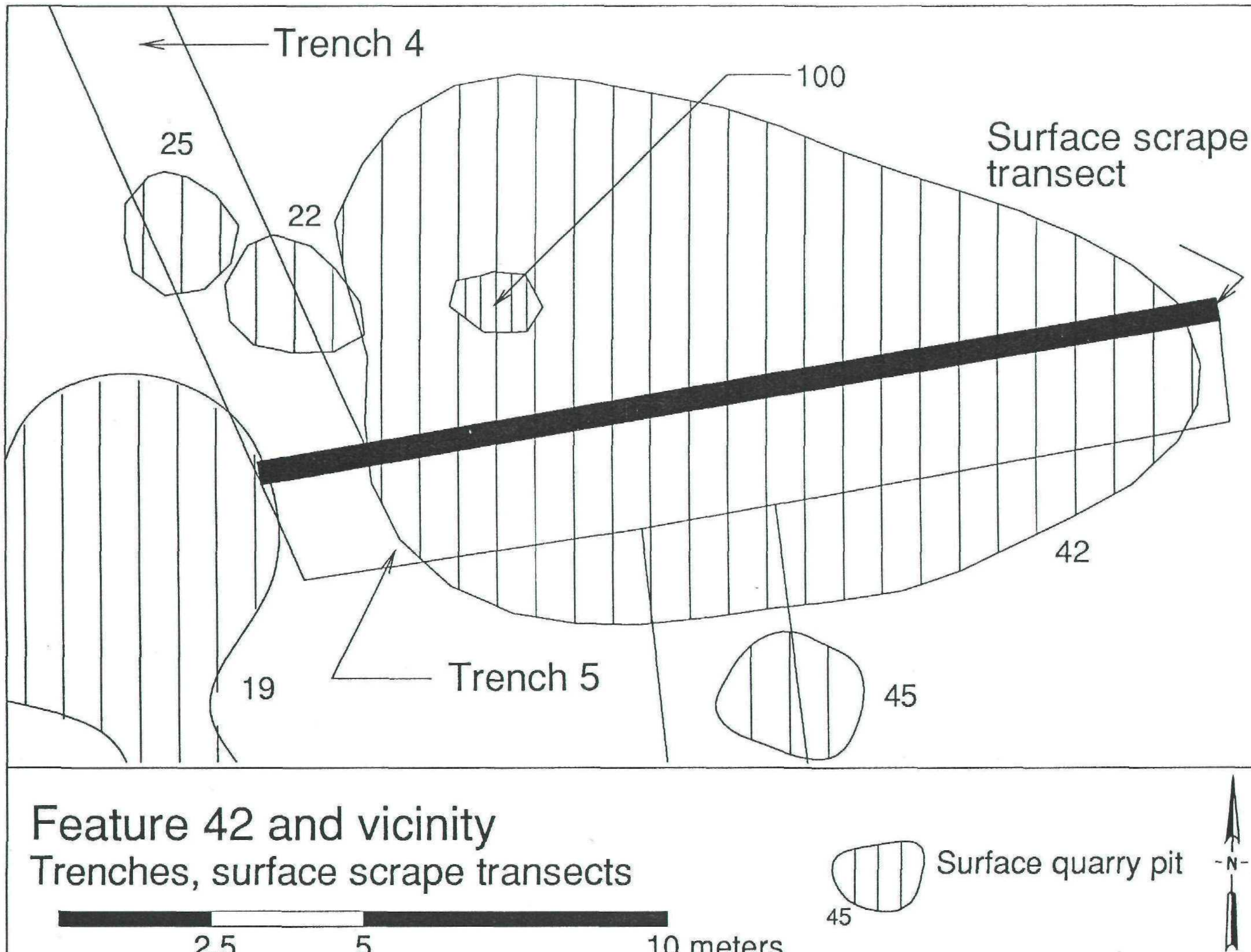


Figure 17. Backhoe trenches, excavation units, and lithic transect collections within the Feature 42 quarry pit complex.

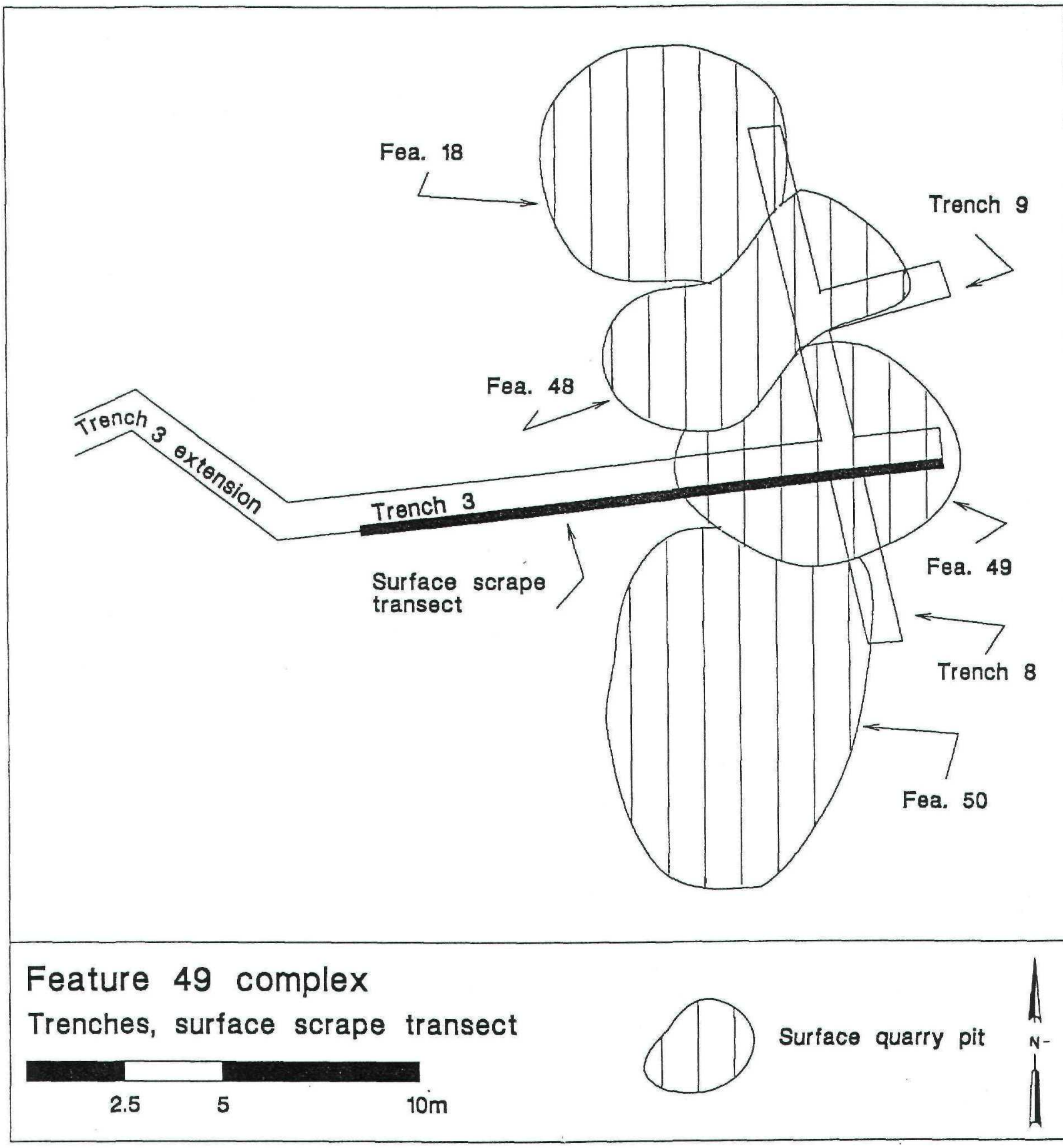


Figure 18. Backhoe trenches, excavation units, and lithic transect collections within the Feature 49 quarry pit complex.

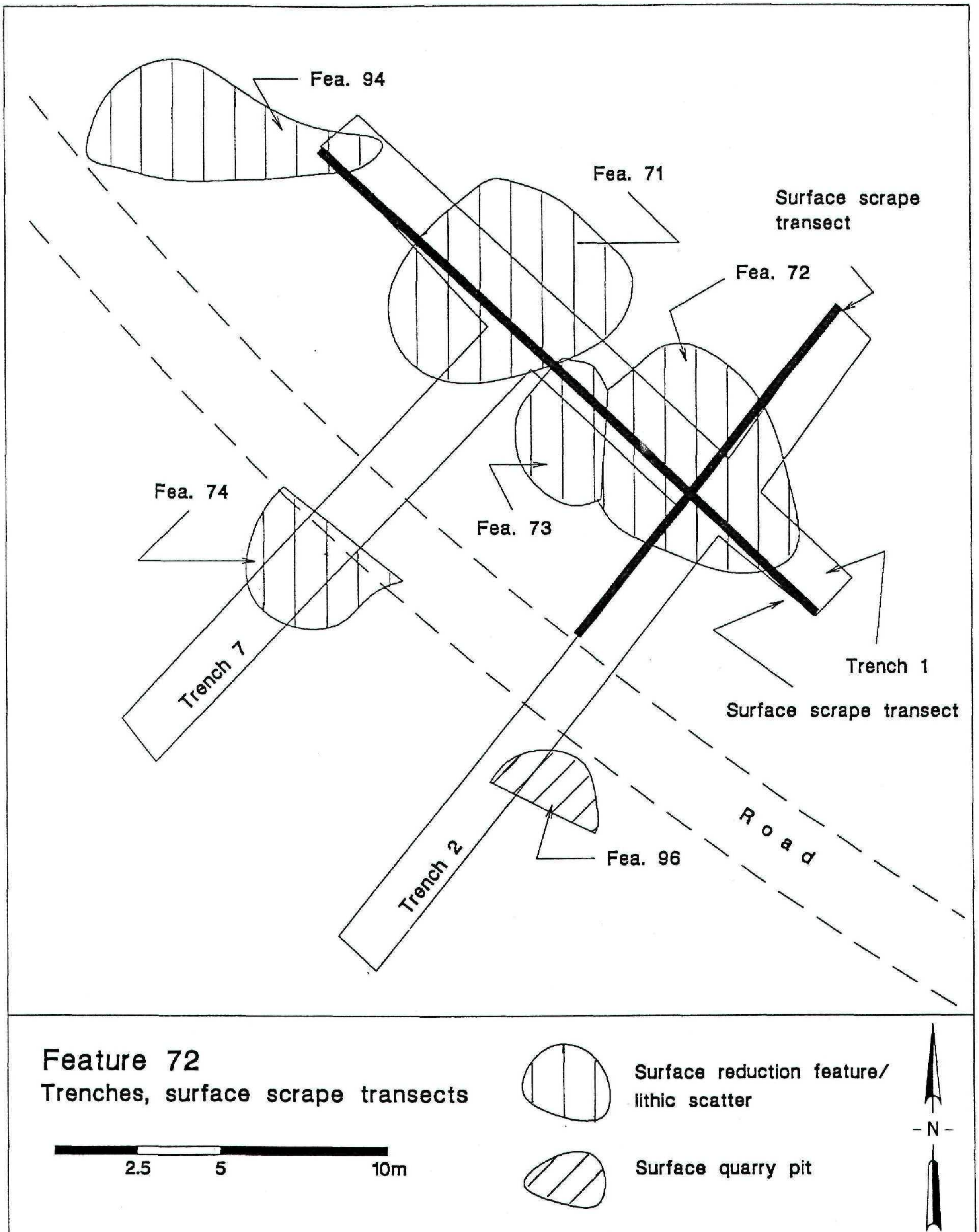


Figure 19. Backhoe trenches, excavation units, and lithic transect collections within the Feature 72 quarry pit complex.

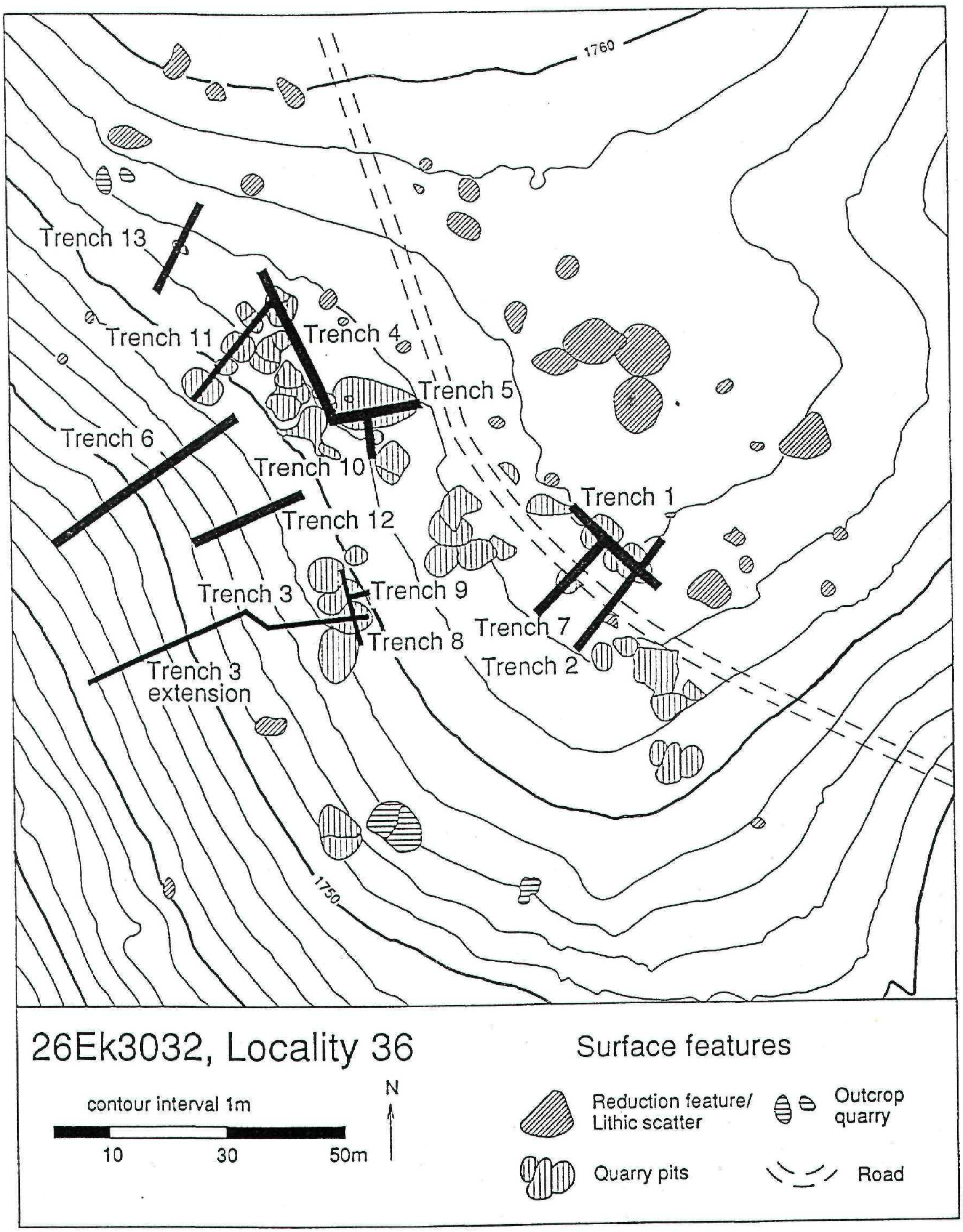


Figure 20. Trench locations.

Subsequent to our first cuts through surface quarry features, we employed additional backhoe trenches to investigate quarry pit complexes more fully and to explore non-feature portions of the site. Near Feature 22, Trench 11 was excavated through Features 11, 12, 13, 30, and 31, and Trench 10 was excavated perpendicular to Trench 5 in the vicinity of Feature 42 (cf. Figures 16, 17). Perpendicular to Trench 1, an additional trench (Trench 7) was excavated parallel to Trench 2; excavation of Trench 7 was designed to investigate the substrate for buried quarry pits.

A short extension of Trench 3 (the "dog leg"; cf. Figure 18) was dug in the vicinity of Feature 102 to reveal an additional profile of the buried pit; the trench then was extended approximately 30 m downslope to explore the area for additional buried features (which were not encountered). Finally, we employed three backhoe trenches in areas with no visible surface features; Trenches 12 and 13 were placed within inter-feature areas to check deposits for buried features and Trench 6 to expose a soil profile for geomorphological investigations (cf. Figure 20).

Both walls of each trench were cleaned, straightened, and examined closely by the project geoarchaeologist who recorded general observations regarding stratigraphy, geomorphology, and pedogenesis, and evaluated the utility of trench wall profiles for interpreting geological and cultural processes operating at Locality 36. Key profiles were selected for closer study and documentation through detailed stratigraphic description and profile drawings. Since backhoe trenches were excavated in groups of intersecting trenches in each of three areas (A, B, and C), at least one wall of each intersecting trench was profiled and described. Of isolated Trenches 6, 12, and 13, located on the steep slope below the quarry, only the north wall of Trench 6 was profiled. In Trench 3, only the north wall of the dog leg extension was profiled. Soil samples were collected for sediment analysis during the process of description.

Many strata in quarry pit deposits consisted mostly of debitage, thus informing of technology as well as cultural and geological site formation processes. Technological data were recovered by a lithic analyst who assayed the technological attributes of over 100 strata in the field (cf. Chapter 4). Each field assessment was documented with a small witness sample to provide a reference collection for future researchers.

Backhoe trenches facilitated collection of charcoal samples, not only to date the use of the quarries but to examine the possibility that fire was used as an aid to toolstone extraction. While the excavation team was still in the field, charcoal retrieved from the (buried) Feature 102 quarry pit exposed in Trench 3 was subjected to radiocarbon assay. Upon receiving a rather early date for the sample (ca. 4000 years B.P.), three excavation units (Units 588, 589, 590) were placed at the edge of Trench 3 in hope of documenting temporal technological variation.

Reduction Feature Excavations and Non-feature Area Sampling

Based on our initial inventory of the numerous reduction features occupying the northern and northeastern portions of the site, we selected eight features for surface collection and excavation (Features 6, 38, 63, 70, 84, 86, 87, and 92; Figure 21). These were chosen to reveal the range of variation expressed in surface manifestations. Although the size and number of units varied, most were explored by a series of 50 cm x 50 cm randomly placed excavation units employing 1/4 in. mesh screen. The random placement of small units in these features assisted in retrieving data relevant to the structure of isolated lithic events while reducing overall assemblage sample size.

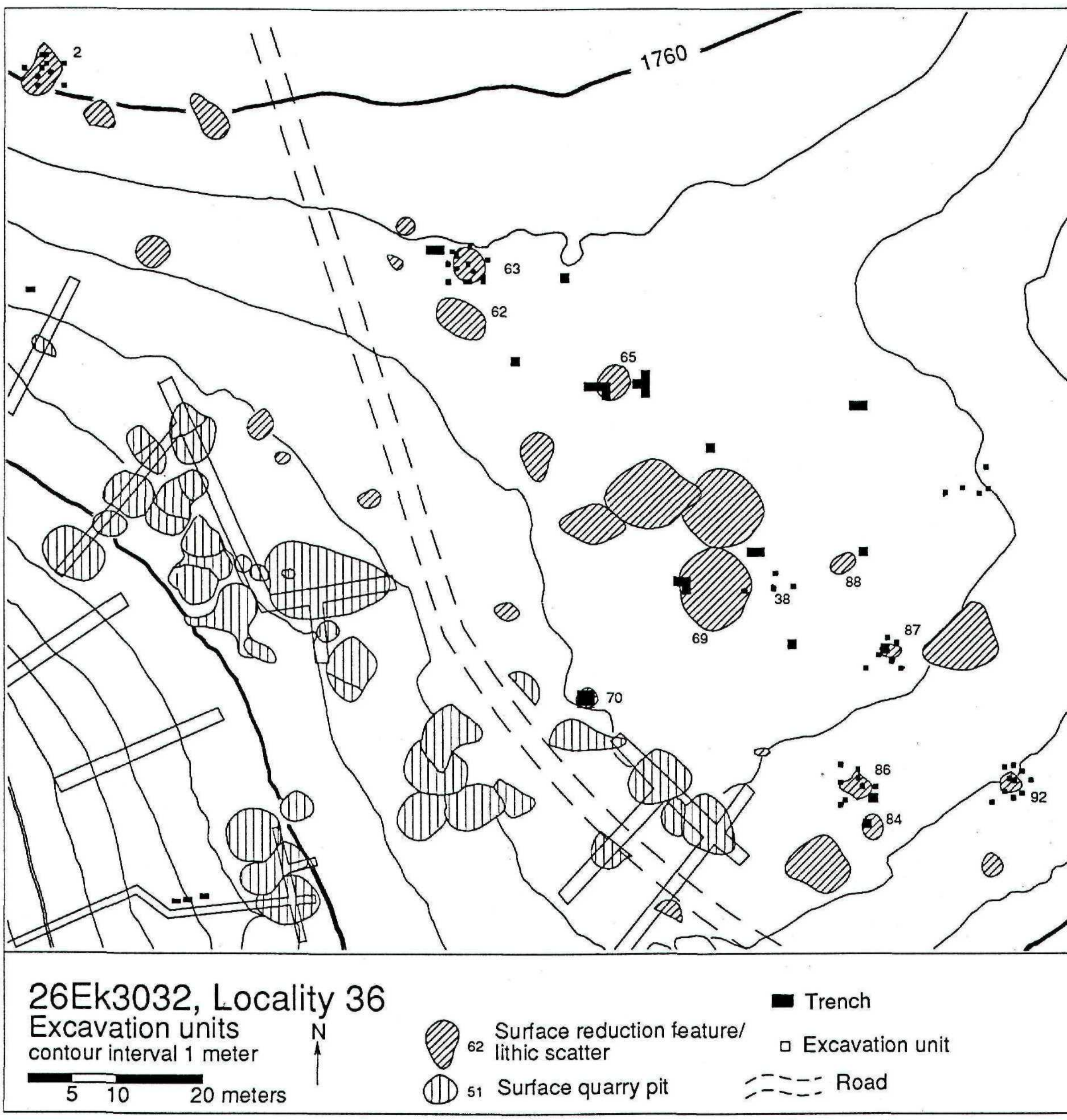


Figure 21. Reduction feature/lithic scatter features selected for surface collection and excavation.

Limited excavations also were conducted in two non-feature portions of the site. In the northeastern area, surface survey identified a delicate, bifacially pressure flaked tool and a late stage biface fragment about one meter apart; both artifact types are rare at the locality and probably represent non-quarry related activity. Their presence (and close proximity to one another) prompted placement of five 50 cm x 50 cm excavation units to explore for additional data; excavations found only a few flakes and no additional tools.

A recent bulldozer cut (Feature 8), located approximately 15 m northwest of the Feature 22 quarry pit complex, had exposed a dense concentration of opalite flakes and chunks ca. 10 cm below the existing ground surface. To explore the possibility of a buried surface, we excavated a 1 m x 50 cm unit immediately adjacent the bulldozer disturbance. Excavations (and subsequent backhoe trenching [Trench 13]) encountered bedrock immediately below surface, capped with abundant non-cultural opalite colluvial cobbles and exfoliated chunks of bedrock amid a few flakes and pieces of shatter.

Mechanical Surface Scraping

We employed a road grader to remove surface loess deposits (ca. 30 cm deep) in the northeastern part of the site in hope of discovering buried reduction features and/or hearths (total area scraped was ca. 45 m x 95 m; Figure 22). The results of the exercise disclosed a single reduction feature, five hearths, and one charcoal scatter (a possible hearth; Features 105-110); their discovery prompted our excavation of 1 m x 1 m units within and adjacent the features to collect datable charcoal and sample associated deposits (Figure 23). Further, in order to sample inter-hearth areas (in part, to secure the "cultural integrity" of the hearth features), we excavated five disjunct 1 m x 1 m units; no charcoal was encountered and artifacts were few.

Actualistic and Replicative Experiments

Investigation of prehistoric quarrying techniques was aided by actualistic quarrying and replication experiments, including reexcavation of a prehistorically worked and backfilled quarry pit. The latter was intended to provide a rough estimate of toolstone recovery rates for scavenging from previously discarded debris as well as to assess the rate of extraction of good quality, fresh toolstone. Because we used tools and techniques similar to those used in the past (including local hammerstones of various sizes and materials, bone and antler digging sticks, and wooden wedges), we were able to estimate the size range of raw material packages that may have been extracted by prehistoric quarriers. In conjunction with previous experiments at Tosawihi, these efforts investigated costs of prospecting for toolstone and evaluated the relative utility of a variety of extraction techniques and quarrying tools.

Previously established biface reduction sequences (Callahan 1979, Bloomer, Ataman, and Ingbar 1992) were followed in experimental biface replications. Toolstone processing was also examined with experimental techniques. Large pieces of opalite were weighed and broken into smaller blocks and flake blanks which then were processed into bifaces. Thus, by producing bifaces similar to those made by prehistoric knappers, we were able to estimate the size of raw material packages needed to manufacture the type of bifaces produced at Locality 36 and the quantities of waste involved in processing, and to calculate toolstone processing rates.

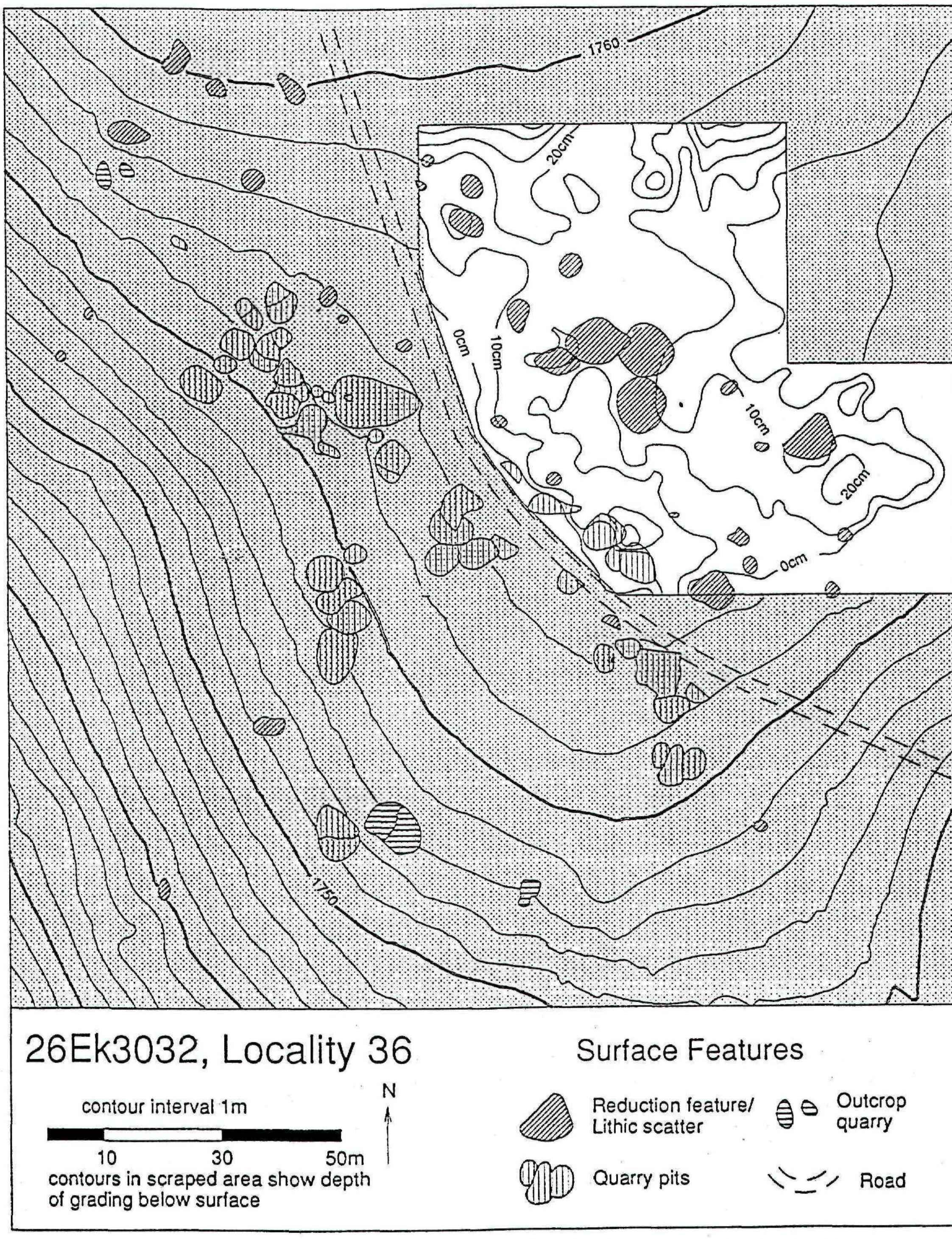


Figure 22. Area scraped with mechanical grader. Contours show depth of sediment removed.

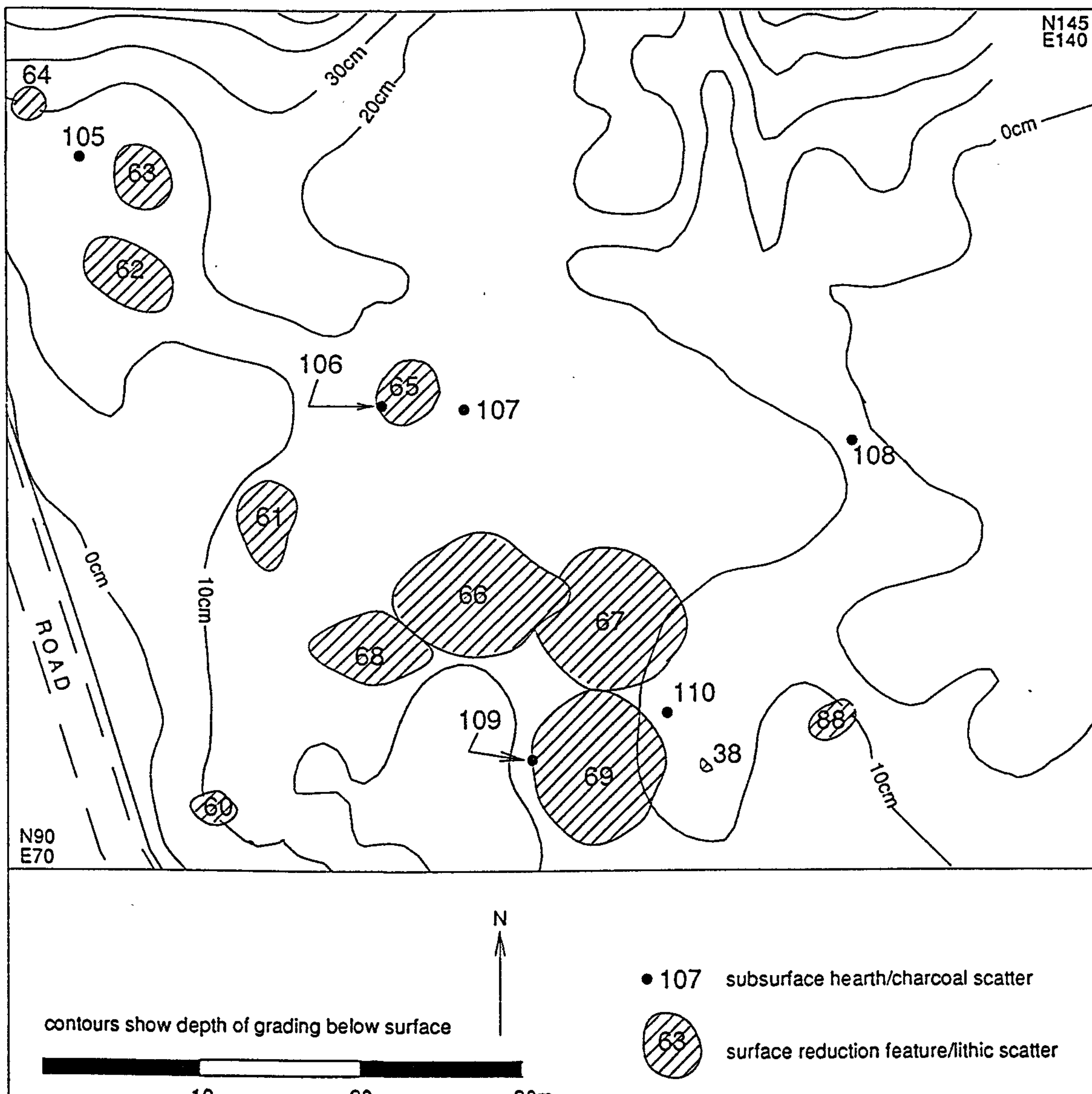


Figure 23. Surface and subsurface features, graded area.

Site Disturbance

Prior to our work at Locality 36, we considered the site to have been only minimally disturbed by recent activities. In 1987, the site was surveyed as part of ongoing work; the road passing through it (cf. Figure 7) was a two-track which had affected its integrity only minimally. By 1990, the road inadvertently had been graded through a large quarry pit complex (part of Area A), a portion of which was disturbed to a depth of approximately 20 cm. This disturbance leveled several quarry pits in Area A before we had an opportunity to map them. One of the only datable (and earliest) artifacts recovered from the site, a fragment of an obsidian stemmed point, was recovered from the disturbed portion of the road; its associations are equivocal.

An additional disturbance occurred after completion of mitigation and was monitored by IMR staff. It involved mechanical removal of the lower slope of the western edge of the site (Figure 24). No subsurface features were noted, although erosion of existing *in situ* deposits upslope may increase.

Processing and Curation

Upon transfer of field collections to the laboratory, artifactual materials (with the exception of bone, soil, and carbon samples) were water screened; cleaning of formed artifacts was supplemented by brushing with soft toothbrushes. Bone artifacts were dry-brushed only. Formed artifacts were numbered individually; debitage, faunal remains, and flotation samples were bagged and numbered as lots. Physical numbering of an item was accomplished with black or white drawing ink, sealed with a layer of clear nail polish (lacquer).

A computer generated catalog was compiled from analytical artifact databases, and provides basic information on provenience, raw material, count, weight, and storage box number.

All artifactual material was bagged by artifact class, then by reference and specimen numbers in .002 or .004 mil plastic bags. Each ziplock bag contains a paper provenience tag and an artifact lot. The bags are packed in one cubic foot cardboard boxes. The collection consists of approximately 120 boxes. Each box is boldly labeled with IMR project number, the site name: "Tosawihi", box number, site and locality number: "26Ek3032, Locality 36", and a brief list of contents.

The artifacts recovered from Locality 36 will be curated under arrangement with the Nevada State Museum, Carson City, where previous Tosawihi collections have been stored. Paper copies and computer disk copies of the catalog, paper copies of field notes and photos, projectile point keying forms and other analytical data, and the final report will be curated at the museum as part of the collection.

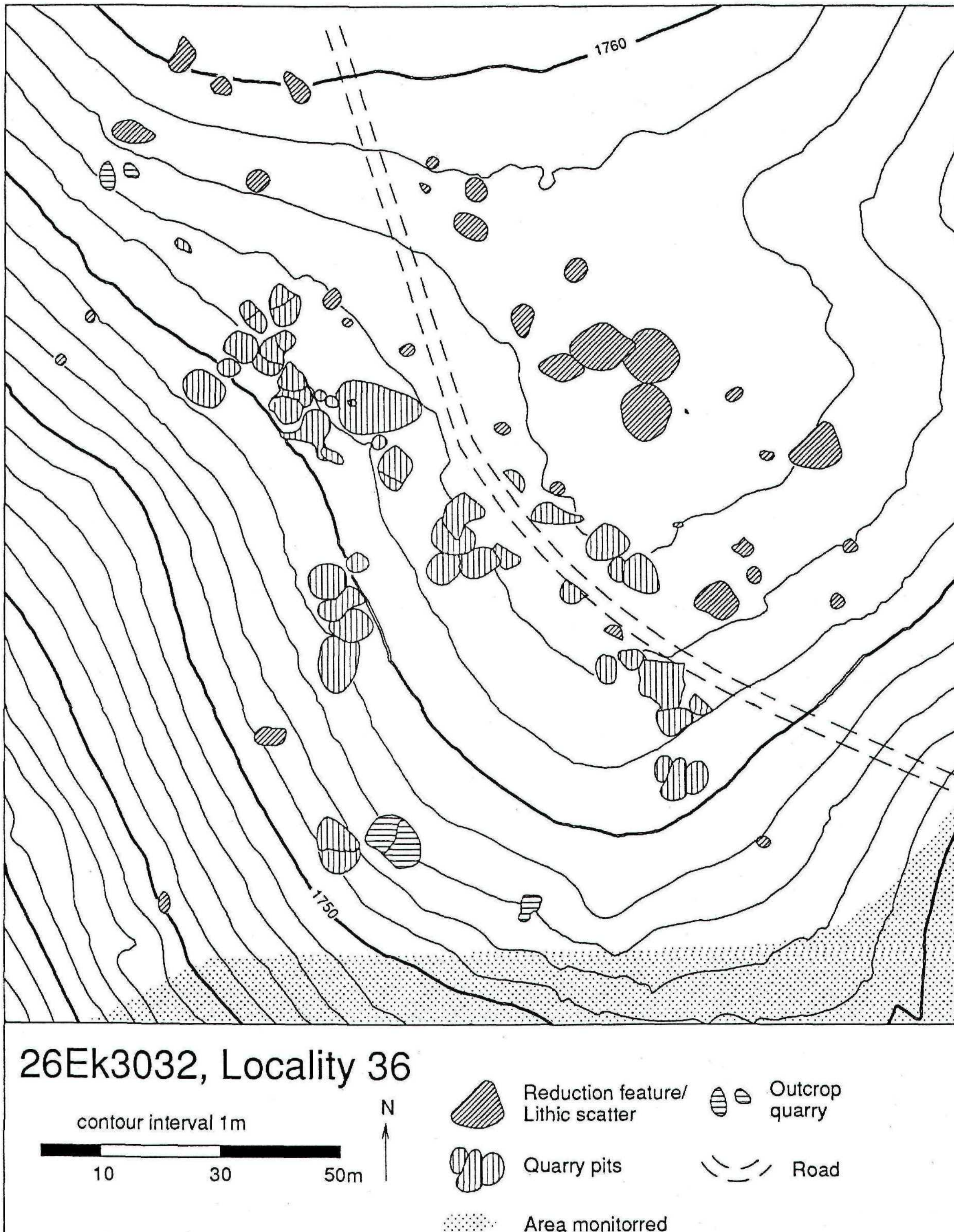


Figure 24. Area monitored during post-investigation development.

Chapter 4

DEBITAGE

Eric E. Ingbar, Kathryn Ataman, and Mark W. Moore

This chapter describes and analyzes debitage recovered from Locality 36. We introduce Tosawihi lithic technology as revealed by earlier research, present the techniques and sampling of debitage recovery from Locality 36, give the methods used to analyze it, and summarize our conclusions. We defer discussion of debitage distributions to later chapters.

Previous research (Ataman and Bloomer 1992; Bloomer, Ataman, and Ingbar 1992; Elston and Raven 1992) has shown that production of bifaces was a primary goal of prehistoric work at Tosawihi. Biface production, measured by reduction stage, changed with distance from quarry sources (Ataman and Bloomer 1992; Raven 1992a). The transport of bifaces away from quarries, and later away from the Tosawihi vicinity, followed the law of least effort: few bifaces were moved (even a few hundred meters) from quarry sites prior to removal of most unnecessary toolstone mass (Raven 1992a). The removal of mass also shapes bifaces into what we regard as "stages" of biface reduction; sites more distant from opalite sources exhibit higher proportions of later stage reduction. Exceptions to this generalization tend to prove the rule: *thin* early biface blanks have been found up to 12km from the quarries. Little evidence of local use of opalite bifaces was found in earlier research; even 12km from the nearest opalite outcrops, opalite bifaces were used rarely (Ataman and Bloomer 1992). If a "production sphere" is defined as the area in which tools were produced but not actually used, it seems that the opalite biface production sphere extended at least 12km from toolstone sources.

The research discussed above relied on data from a large number of non-quarry sites and from only a few, relatively isolated, quarries. The most intensive opalite exploitation occurred within the boundaries of site 26Ek3032, wherein Locality 36 is one of numerous quarries. Thus, study of Locality 36 constitutes our first glimpse at the center of the production sphere.

Foremost among the several research topics addressed in this chapter is the question of *what* was produced at Locality 36, and in what quantity. Obviously, opalite toolstone extraction was important and, to some degree, debitage analysis permits examination of how toolstone extraction was conducted by identifying core (including biface blank) forms created from extracted opalite.

Too, we wish to know what commonly happened to extracted opalite *at the locality*. Hypothetically, the range of options spans a continuum from transport of blocks or large flakes for reduction elsewhere to production of finished tools on the spot. Between these extremes lies a range of lithic production options including removal of unneeded toolstone mass without much shaping of tools, mass removal followed by some initial shaping, and mass removal followed by nearly complete tool production. Because we suspected successful reduction products were removed from the site, debitage provided the most direct testimony on which options were employed. Examination of debitage from quarry pits, from chipped stone reduction concentrations, and from other contexts allows determination of core form, of reduction technology, and of degree of reduction, all of which bear on the question.

An additional question asks why non-quarrying activity ever occurred at Locality 36. The query springs from our interest in how toolstone procurement meshed with general economic and mobility patterns. Prehistoric hunter-gatherers had to outfit their stone toolkits and the least costly way would have been to stage other activities in conjunction with quarry visits. Yet, the

Tosawihi landscape offers few resources to reward such "other activities" (Raven 1992b), so prehistoric strategies of toolstone procurement must have attempted to minimize support, opportunity, and associated costs (Chapter 3). One way to do this is through labor organization and mobility scheduling (Elston et al. 1992), a consequence of which *might* be spatial conjunction of toolstone procurement and other activities, i.e., use of quarries to stage non-quarrying activity. Archaeologically, this should be reflected as tool *maintenance*. For example, edge retouch flakes from tools made on non-local toolstone may reflect the maintenance of active tool edges.

The preponderance of debitage recovered from Locality 36 is opalite. Colors (beige, grey, and white), textures, and inclusions observed in the debitage do not differ from those in the bedrock; undoubtedly, most of the opalite originated at the locale. The few recognizably non-local flakes of opalite, jasper, and chalcedony, as well as rare non-Tosawihi materials (e.g., obsidian), are discussed below. All following analyses and interpretive statements concern locally available opalite unless otherwise noted.

Tosawihi Lithic Technology

Earlier research has revealed the local dominance of biface production (Elston and Raven 1992). Biface production generally proceeds from either a flake/core-based approach or from a block-based approach (Binford and Quimby 1963; Flenniken and Stanfill 1980:24-27). In the flake/core approach, the intended product of initial reduction is a flake blank struck from a core. The core may be of almost any form, so long as it can produce flakes large enough to serve as blanks. Flake blanks then are reduced to bifaces. In contrast, in a block-based strategy the intended blank is the block itself.

The two approaches are not mutually exclusive, since large flakes from block blank production themselves could be used as blanks. More often, however, block blank flakes are not useful as biface blanks, being too small, too weak, or of the wrong shape. Recycling such waste flakes into "chip blanks" (Binford and Quimby 1963) for other tools can be important, but such recycling is not the primary objective in a block-based strategy.

The production of a biface can be seen as occurring in stages (Muto 1971), even though the reduction process is continuous. Reducing a flake-core during the initial production of flake blanks involves raw material acquisition and initial core preparation; maintenance of the core as flake blanks are removed is a potential third stage. An exhausted flake blank core then may become a blank itself, following the process used in a block-based approach. Block-core blank production can be achieved in a single stage of raw material acquisition, or, if two stages are used, acquisition may be followed by initial reduction of the block to a generally appropriate size.

A blank, whatever its genesis, may be used as a tool without modification, or it may be reduced further to a unifacial or bifacial tool. If so reduced, it proceeds through an initial edging stage and then passes through early biface thinning, late biface thinning, pressure flaking, and perhaps haft preparation (e.g., notching). Heat-treatment is a separate process that can occur any time in the reduction process. Although the reduction process is continuous, an item need not have passed through all the analytical stages we impose (cf. Bloomer, Ataman, and Ingbar 1992).

We have summarized the production of Tosawihi flake blank-based bifaces elsewhere (Bloomer, Ataman, and Ingbar 1992). Most Locality 36 blanks may have been derived from block cores, so we focus on their production in the following discussion. Late stages of biface production, reiterated here for the sake of completeness, are the same for both techniques.

Production begins with acquisition of toolstone blocks (i.e., toolstone extraction) from bedrock. Natural cracks and flaws provide avenues of attack to separate pieces from bedrock, dictating the size and shape of extracted pieces. Debris produced as part of the extraction process may include fragments of tuff, the matrix around opalite or stringers within it. As well, angular debris and large irregular flakes generated by tapping and beating on bedrock are common by-products, as are rejected opalite chunks.

Once a piece has been extracted, testing for interior stress planes by removing a few flakes determines how suitable it is for further reduction. Failure along internal stress planes will split the piece without producing conchoidal fractures. Testing also may produce large flakes that terminate on fracture planes in apparent step fractures. Testing flakes also may follow along a fracture plane, yielding a flake with a flatter ventral surface than would have formed otherwise.

Testing may be combined with mass reduction. Mass reduction removes irregularities from a block and trims it to a size appropriate for initiation of blank production. At this point, the piece is in Stage 1 of biface production—blank selection (following Callahan [1979]; cf. Chapter 5). Blank production begins with edging, usually accomplished by percussion flaking. Flakes are driven from the block margins where necessary to form a biconvex cross section. Blank preparation may be necessary only on parts of the block, or the entire block may need attention. Raw opalite (i.e., not heat-treated) is tough and inelastic, requiring considerable force to detach flakes. Therefore, hammer blows must land away from the margins of the block (producing flakes with thick, wide platforms). Marginal strikes cause the margin simply to break off. The entire blank preparation process constitutes Stage 2 of biface production. The amount of blank preparation varies, depending on the initial form. For example, thick biconvex flake blanks need less edge preparation than do subrectangular or tabular blocks.

Following removals designed merely to shape the edge, subsequent flake removals begin to thin the biface (thereby increasing its width to thickness ratio). Such early thinning also may serve to edge the emerging biface, so that platform morphologies may overlap with those of edging flakes. As the facial morphology becomes increasingly regular, early biface thinning flakes become somewhat less thick, propagate more evenly, and tend to carry across the midline of the piece. Patterns of flake removal emerge through this early thinning stage and such patterning often is evident on the resulting flakes. Initial thinning comprises Stage 3 of biface production.

Late initial thinning (Stage 3), and all late thinning (Stage 4), are intended to address the thickness of the biface rather than influence its outline. At Tosawihi, late initial thinning and late thinning frequently was done with soft hammer percussion. Our own experimental knapping of raw opalite found the material too brittle to thin consistently with hard hammer blows. Heat-treatment often occurs at about Stage 3 of reduction, increasing the elasticity of the stone so that it can be thinned more reliably (Bloomer, Ataman, and Ingbar 1992).

Research Methods

Debitage analysis followed a general strategy established in earlier research (cf. Bloomer and Ingbar 1992). Technological analysis, whereby debitage attributes were observed in each sample, served as one analytical technique. Mass analysis, whereby flakes were size-graded, counted, and weighed, served as a second, equally important, technique. We also used a simple sorting of platform-bearing flake fragments from edge marginal fragments, weighing and counting each group, and weighing angular debris as an ancillary analytical technique on some sample sets.

Data recovery at Locality 36 yielded a lot of debitage, prompting our use of a random sampling plan to select samples from a variety of contexts. Comparison with samples not randomly selected then served to confirm or refute analytical outcomes based on the random sample. Random sample selection is reviewed further below.

Technological Analysis

Current debitage research involves two lines of inquiry—attribute analysis and typological analysis. Attribute analysis involves observation of specific attributes (often reflected as metric measurements) of individual flakes; typological analysis observes *flake types*. Identification of flake types depends on the subjective observation of many attributes measured and recorded in attribute analyses. Rather than giving each attribute analytical importance, the sets of flake attributes subjectively are summed (often using polythetic criteria) to comprise a single type determination.

In our previous work, and here as well, we have ignored attribute analysis in favor of typological analysis of debitage assemblages (Bloomer and Ingbar 1992), doing so for two reasons: (1) the outcome of many attribute analyses simply reaffirms the existence of flake types, which appear in such analyses as attribute clusters; (2) experienced lithic analysts can conduct typological analyses more quickly. Flake typology is best derived from prior knowledge or insight concerning the technology under study. Previous research at Tosawihi identified the major components and goals of the area's lithic industries (Ataman and Bloomer 1992). Experimental replications of opalite biface production served as controlled cases with which to train analysts and calibrate their observations. Earlier technological analyses (cf. Bloomer and Ingbar 1992) employed three major debitage types: angular debris, uninterpretable flake fragments, and interpretable flake fragments. The latter was subdivided into six flake types: primary decortication, secondary decortication, interior flakes, bipolar flakes, pot lid flakes, and biface thinning flakes. Five further subtypes of biface thinning flakes were distinguished: edge preparation, early stage thinning, late stage thinning, pressure flakes, and all other bifacial flakes. Each was given equal analytical importance whatever its level of subclassification, because each was considered diagnostic of different kinds and stages of reduction. Edge preparation flakes, early stage thinning flakes, late stage thinning flakes, pressure flakes, interior flakes, and both types of decortication flakes determined reduction techniques and reduction stages present in Tosawihi debitage assemblages.

With the benefit of hindsight, we simplified the typological analysis strategy. Rather than recording types, subtypes, etc., to be lumped later into synthetic interpretive categories (e.g., initial blank preparation), we put our observations directly into an interpretive framework. Based on previous research, five interpretive categories were used to record reduction stage and type of reduction within a sample. We isolated quarrying, mass reduction, blank preparation/initial edging, early biface thinning, and late biface thinning. Description of these categories, their flake types, and their attributes follows a brief digression on how this system was used to record a sample.

Any given sample can be characterized by five categories of debitage (in letters, Q, M, B, E, and L, respectively). If a category is absent, then its place may be left blank. If present in trace amounts, a lowercase letter encodes that fact. If a category of flakes is frequent but does not dominate a sample, a capital letter may be used. A dominant category is denoted with an underscored, asterisked, or bold-faced capital letter. There are, then, four possible attribute states for any given category (blank, lowercase, uppercase, emphasized uppercase); these can be combined as needed (in serial order) to characterize a sample. Theoretically, there are 4 to the 5th power combinations of letters. These 1024 permutations of sample characterization were adequate for our needs. We also recorded incidences of heat-treatment, burning, and soft hammer reduction.

Typological Analysis Categories and Incidental Observations

Typological analyses often depend upon a polythetic set of criteria. Thus, replication of any typological analysis by other researchers is difficult. Analytical comparisons are hindered, as well. We explicitly describe the typological categories employed at Locality 36, hoping that some of these pitfalls can be avoided. The type descriptions presume familiarity with simple lithic technology; Crabtree (1972) is our standard reference. Each type description begins with a general description of the category, followed by a description of specific constituent flake forms.

Quarrying (Q)—Quarrying debitage (Figure 25) results from the extraction of toolstone from bedrock. The piece extracted could be a large block, a large flake, or simply clasts removed to expedite access to more useful parts of bedrock. Quarrying debris consists of large (greater than 6 cm maximum dimension) pieces of angular debris, non-orientable block fragments (cf. Chapter 5 on modified chunks), and very large (greater than 20 cm maximum length) flakes with cortical platforms and dorsal cortex cover. The latter are infrequent at Locality 36. The most common evidence of quarrying in the Locality 36 assemblages consists of large angular debris, often having some cortical surfaces. Cortex is difficult to distinguish in Tosawihi opalite, since it often occurs with stringers of poorly silicified and unsilicified material. We use the term here to denote only obvious weathered tuff exteriors.

Mass Reduction (M)—Mass reduction is the initial step in processing toolstone, the removal of unnecessary material from a block or slab of stone. Removing mass shapes the stone; the basic intent is creation of a piece of stone suitable for further reduction. Large flakes produced as blanks for biface production are not likely to need much mass reduction, so they primarily indicate blank production from blocks or slabs of stone. Flakes resulting from removal of mass exhibit evidence of hard hammer blows, and platforms frequently have been shattered or are large and plain (Figure 26). Ring cracks are common in platforms. Unshattered platforms are single-faceted. Planar outline of mass reduction flakes is highly variable. Cross-section and long-section can be flat, but more often is very irregular. Complex dorsal scar morphology is rare. Dorsal scars parallel the flake axis and originating from the same platform edge are not uncommon. Ventral morphology is characteristically irregular due to propagation of the force of the blow into the stone (rather than oblique to it); compression rings and hinge terminations can be common in mass reduction flakes but are not infallibly diagnostic. Flake size is highly variable; in Locality 36 debitage, we observed mass reduction flakes ranging from 6cm to 20cm long. Core reduction flakes from cores with unprepared platforms or simple platforms are a specific subset of mass reduction flake and share the morphological attributes discussed above. Core reduction flakes show evidence of more controlled removal—more detailed platform preparation, more regular sectional and planar shapes. Because they comprise a subset of mass reduction flake discriminating core reduction, their isolation requires assessment of the proportion of well-controlled mass removal flakes to poorly-controlled mass removal flakes in an assemblage. We noted assemblages that contained high incidences of well-controlled mass reduction flakes as possible core reduction assemblages.

Blank Preparation (B)—Blank preparation flakes (Figure 27) are detached in the initial edging stage of biface reduction. The purpose of blank preparation is to create a bifacial edge from a rectangular or subrectangular edge. Typically, flakes are removed by hard hammer percussion, but they can be detached with a soft hammer as well. Three types of flakes are subsumed: edge

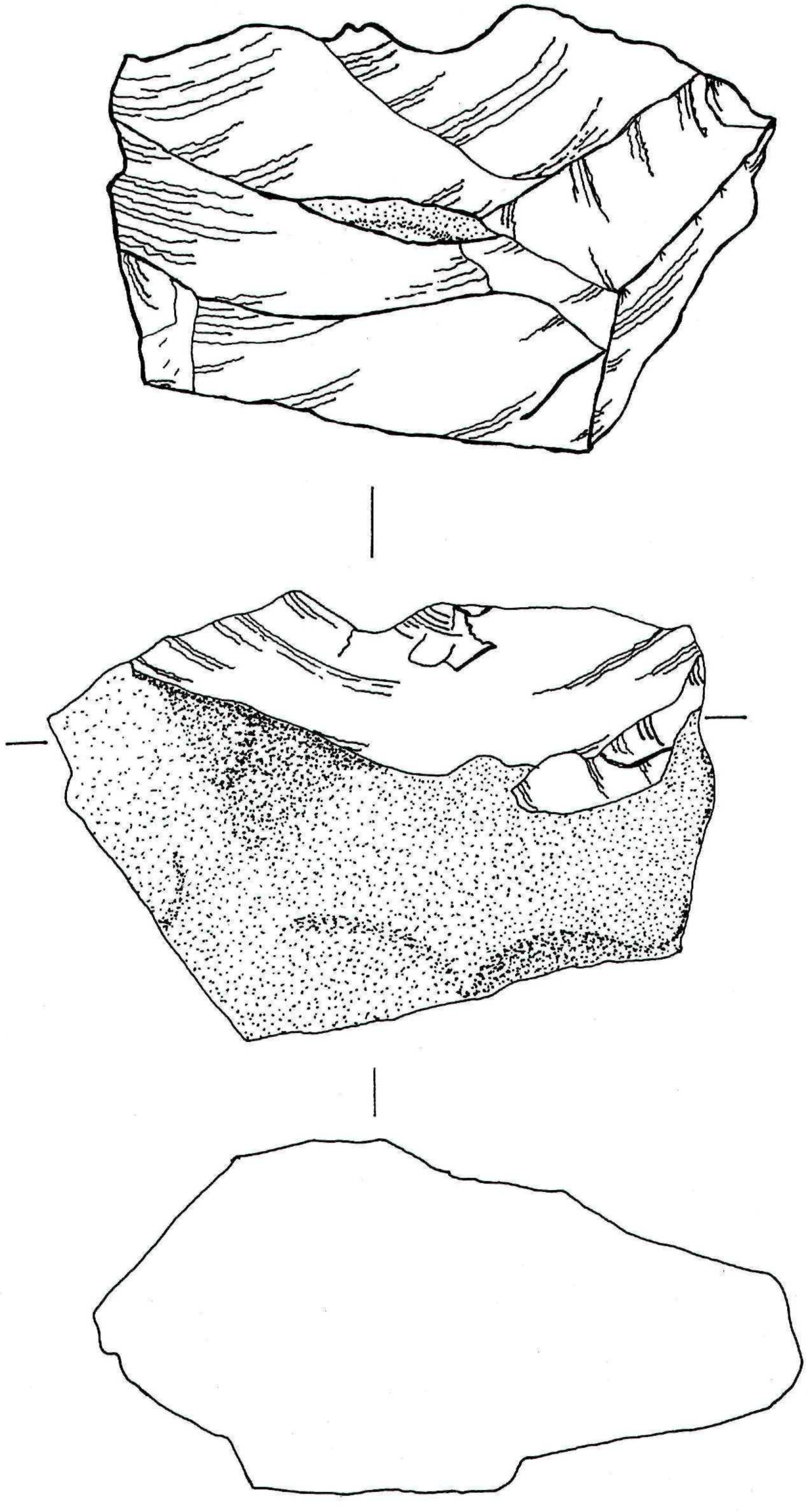


Figure 25. Typical piece of quarry debitage.

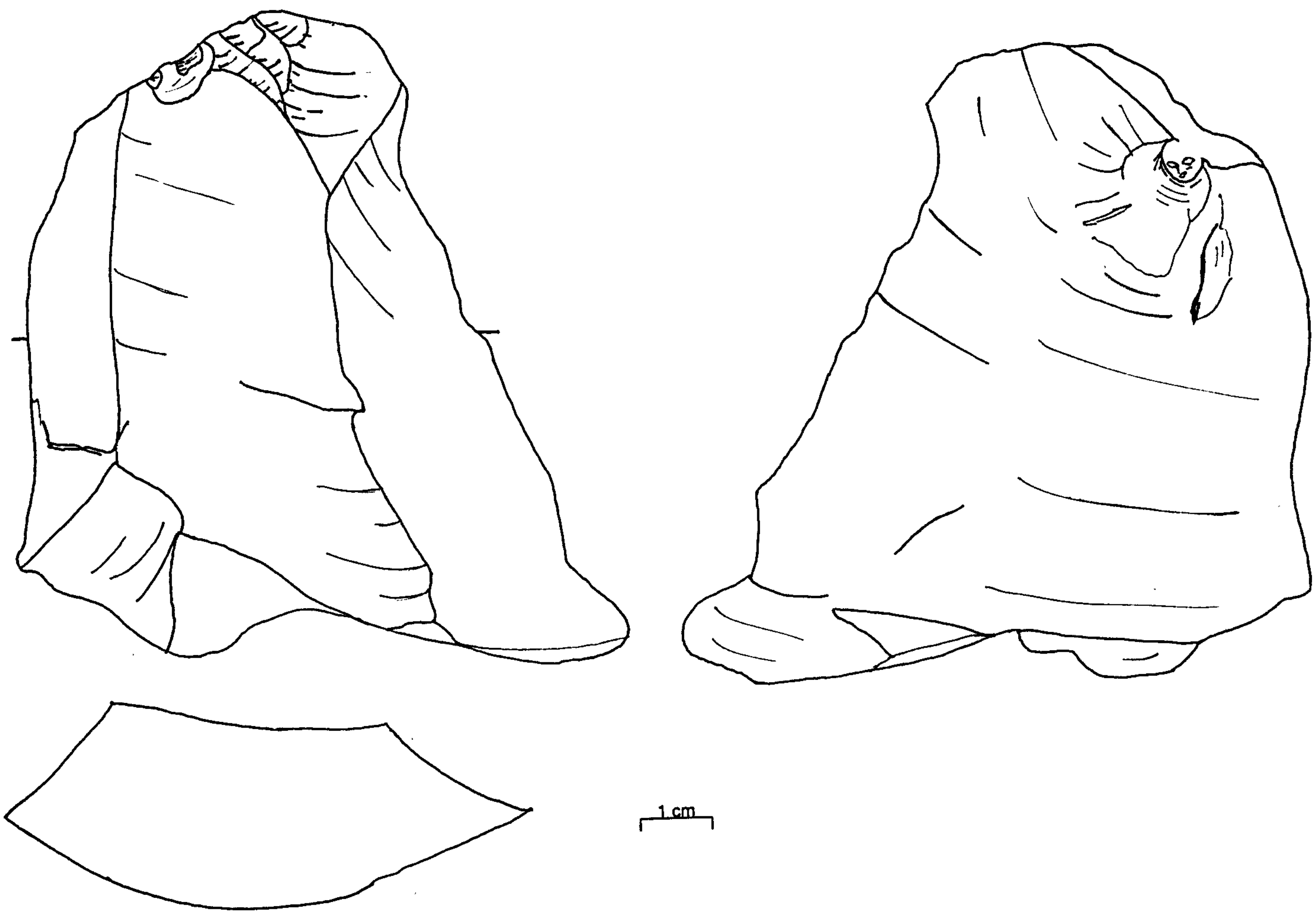


Figure 26. Typical piece of mass reduction debitage.

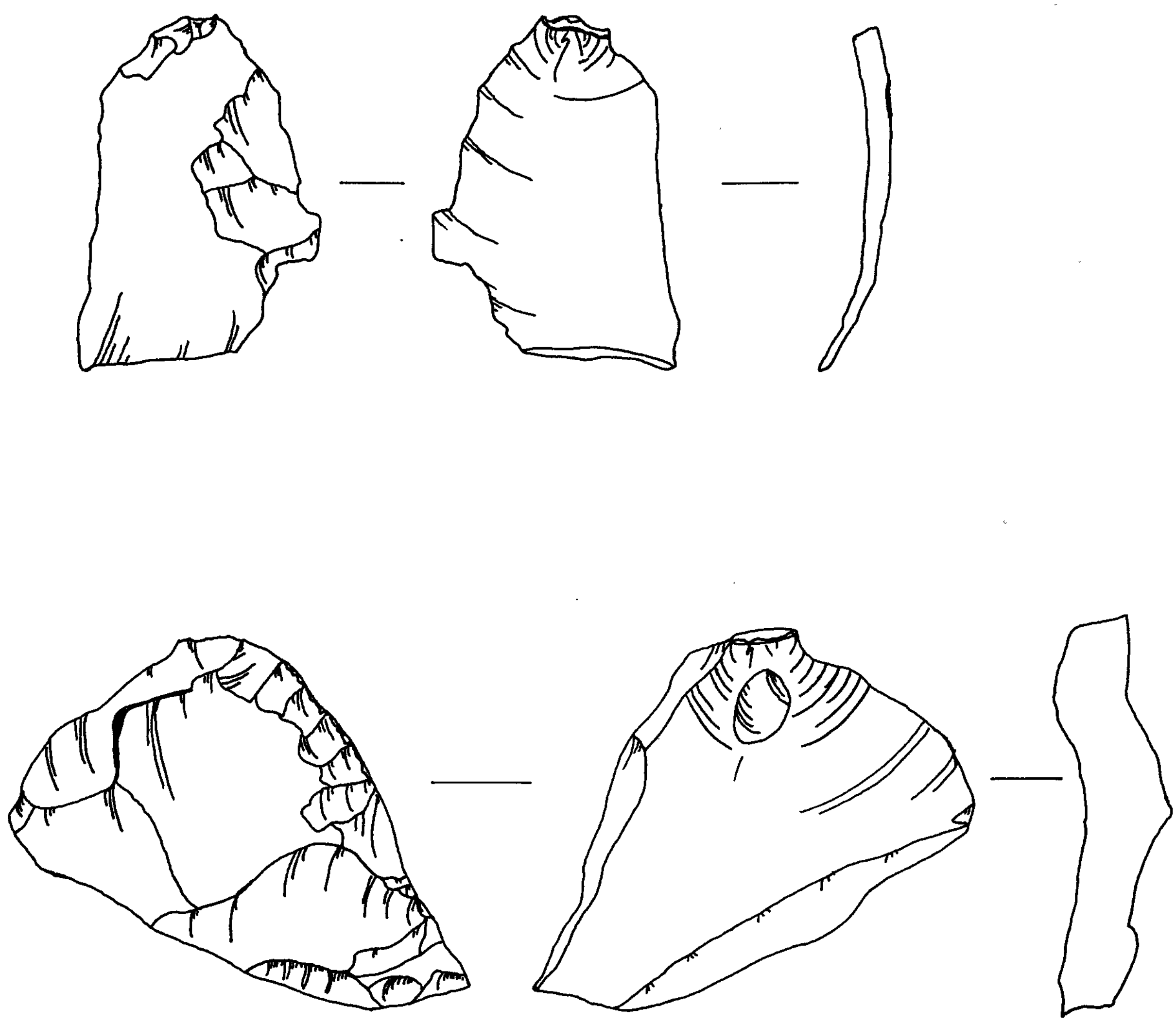


Figure 27. Blank preparation flakes. a. edge preparation flake; b. flake struck from square edge.

preparation flakes, alternate removal flakes, and bulb removal flakes. *Edge preparation flakes* are removed unifacially in sequence along an edge and generally have single facet platforms; the blow is applied slightly back from the edge of the platform. They tend to flare perpendicular to the square edge, so as to be wide but short. Cross-sections of such flakes are usually thickest at the bulb of percussion. Edge preparation flakes are highly variable in size and can be quite large (greater than 8cm maximum length). Dorsal attributes are especially distinctive, since such flakes retain edge morphology. *Alternate flakes* are similar to edge preparation flakes, but where edge preparation flakes are removed unifacially in sequence, alternate flaking proceeds by removing a flake from each face, so that the removal from one face creates a platform for the next removal from the other. Thus, the locations of platforms in relation to flake axes differs. Most attributes of alternate flakes are the same as those of edge preparation flakes with the following exceptions: one side of the platform has steep lateral edges, triangular cross-section, negative flake scars on the dorsal surface from prior alternate flake removals, and the bulb of percussion and compression rings often are oriented oblique to the platform. *Bulb removal flakes* are produced by removing the contact point and some portion of the bulb of percussion from the ventral surface of a flake blank. They represent unequivocal evidence of the edging of flake blanks. Bulb removal flakes can be struck from raw Tosawihi opalite using either hard or soft hammer percussion. Platform characteristics are highly variable. The key attributes of bulb removal flakes lie on their dorsal surfaces, which retain the exterior ventral surface of the flake blank, including the cone of percussion and/or compression rings.

Edge preparation flakes are not wholly unique to the preparation of blanks for thinning. They also are produced in early biface thinning, but generally in much lesser frequencies. Furthermore, those with relict original block surfaces (evidence of edge preparation) often can be distinguished.

Early Biface Thinning (E)—This category includes both hard hammer and soft hammer early biface thinning flakes (Figure 28). Hard hammer early biface thinning flakes are produced in small numbers in the initial edging of a biface (Stage 2 of biface reduction) and in large numbers during the initial thinning of bifaces (early to mid-Stage 3 of reduction). Removal of hard hammer flakes thin the biface and can reduce biface width by removing its edge. This advances the production of a regular edge contour begun in blank preparation. Consequently, the width to thickness ratio may not change during this process. Attributes of hard hammer early biface thinning flakes include broad multifacet or single facet platforms, the force applied slightly back from the edge; as well, the flake expands away from the platform, flakes in long section may curve and be somewhat thick with negative flake scars (of several orientations) on the dorsal surface, prominent cones of percussion may be present, specimens may exhibit relatively acute (less than approximately 60 degrees) platform to dorsal surface angles, and terminations may feather or hinge.

Soft hammer early biface thinning flakes are detached so as to thin early stage bifaces that already have regular edge contours, e.g., a thin well shaped flake blank. In contrast to hard hammer early biface thinning flakes, soft hammer thinning flakes have multifacet platforms resulting from force applied on or near the flake margin. The platforms often are abraded or ground to alleviate slippage of the percussor. They are thinner than hard hammer thinning flakes, but have more prominent dorsal ridges than soft hammer late thinning flakes. Rather than having distinct cones of force, they tend to display indistinct points of percussion, diffuse cones of force, and lipped platforms resulting from initiation by a bending fracture. The distal terminations usually are feathered. Size of both soft hammer and hard hammer early biface thinning flakes is conditioned strongly by initial biface size. Early thinning flakes rarely extend from edge to edge, usually not even crossing the midline of the biface.

Late Biface Thinning (L)—Late biface thinning flakes (Figure 29) generally are removed by soft hammer percussion to thin the facial surfaces of a biface and to make the topography of the faces more regular. Late biface thinning begins late in Stage 3 reduction and continues through Stage 4. The flakes cause little loss of width, serving primarily to reduce thickness. Platform characteristics and plan outline are similar to those for soft hammer early biface thinning flakes, from which they differ in degree but not in kind. Late thinning flakes tend to have slighter curvature in long section and to be thinner and more "ribbon-like." Dorsal ridges are more subdued than among early biface thinning flakes because the faces become much more topographically regular. Dorsal flake scars from previous removals frequently show multiple orientations in the prior flake scars. Dorsal scar patterns overall are more complex than on early biface thinning flakes, due partly to the size of late thinning flakes, which propagate much more evenly on smooth faces. Thus, in relation to biface size, late biface thinning flakes are "very substantial" in size (Young and Bonnichsen 1984:188). Flenniken (1987) estimates that late biface thinning flakes usually run slightly less than half the width of the biface, so their complete length can be used as a rough estimator of biface size.

Heat-treatment and burning—Heat-treatment was recorded whenever it was observed in a sample. Distinctive characteristics of opalite when heated include changes in luster, texture, and compliance (cf. Bloomer, Ataman, and Ingbar 1992). Heat-treatment of opalite increases its elasticity, permitting flakes to be removed more predictably and/or with less force. Force propagates better in heat-treated opalite, resulting in generally larger flakes. Failed heat-treatment, which sometimes cannot be distinguished from accidental burning, can create invisible flaws that lead to distinctive curvilinear or "crenated" breakage patterns (Bloomer, Ataman, and Ingbar 1992; Purdy 1975), but burned opalite usually is distinguishable from heat-treatment, as the material crazes and discolors, exhibits pot lid spalls on its surface, and often breaks into cuboid fragments. Heat-treatment was sufficiently common in a few samples that we characterized the heat-treated portion separately from the raw portion.

Soft hammer percussion—Soft hammer percussion is not specifically characteristic of the thinning stage, but we noted soft hammer flake types whenever we observed them. Such recording permitted evaluation of when soft hammer flaking began in the reduction sequence, and it allowed assessment of whether the reduction stage at which production shifted from hard hammer to soft hammer percussion correlates with materials of a particular age.

Mass Analysis

Mass analysis is a simple technique whereby debitage samples are shaken through nested sieves (Table 3). Large samples can be split into fractions prior to sieving. Counts and weights are tallied then for each size grade, and resulting data are converted to sample proportions. Sample proportions and variables then can be used for simple comparisons or in complex statistical models. Both simple and complex interpretive models depend on the (prior) analysis of controlled cases, usually drawn from experimental chipped stone reduction. The primary application of mass analysis has been in the identification of core forms (block cores, bifacial cores, finished tool edges) and biface reduction stages (Ahler 1989a, 1989b; Bloomer and Ingbar 1992).

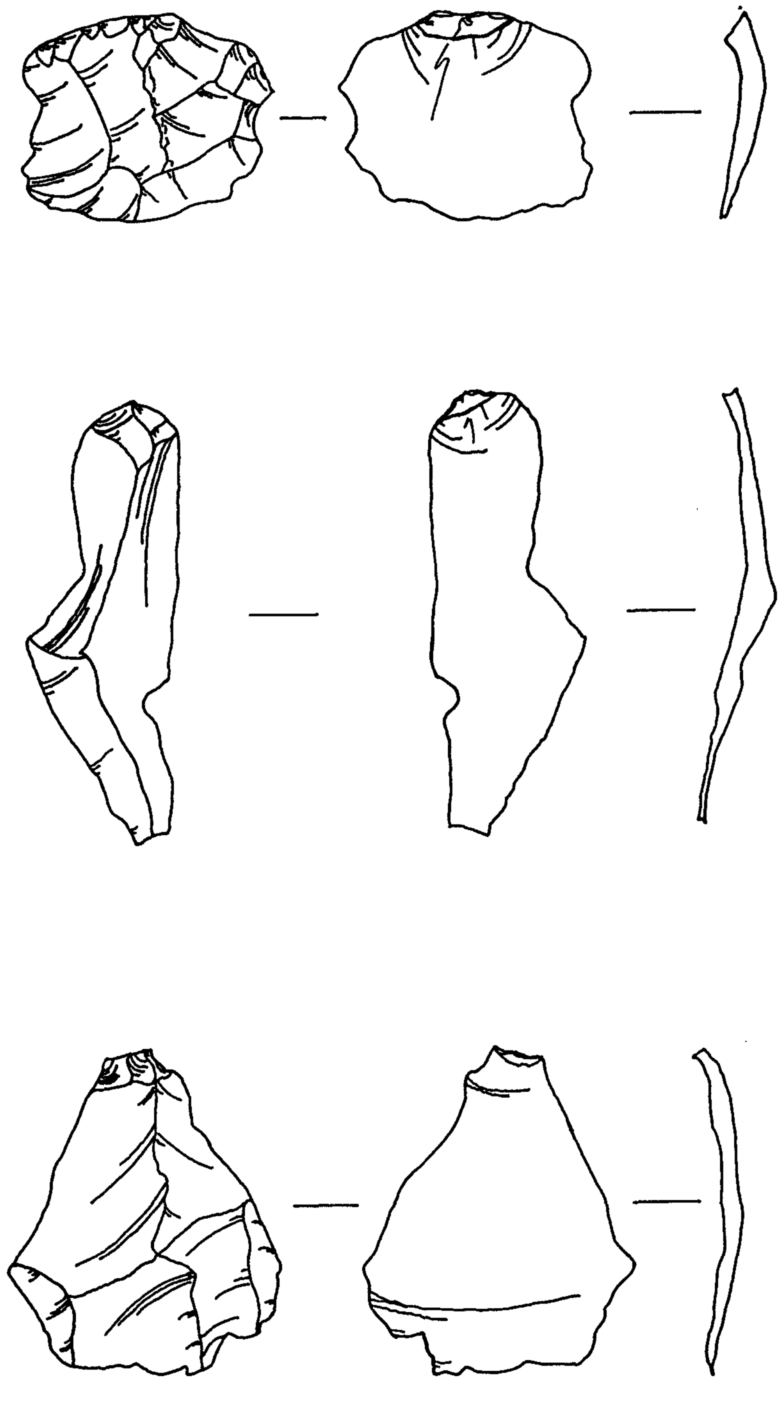


Figure 29. Late biface thinning flakes.

Table 3. Variables Recorded During Mass Analysis of Debitage.

Material type:	1. Opalite	2. Jasper	3. Obsidian
	4. Basalt	5. Other	

Split type: (n), split is 1/n, n=1, 2, 4, 8, 16, 32

Size Grades:

G0 (2" nominal opening)
G1 (1" nominal opening)
G2 (0.5" nominal opening)
G3 (0.25" nominal opening)

Counts and Weights within each size grade:

Count of flakes with platform remnant
Count of flakes with platform remnant and dorsal cortex
Mass (g) of flakes with platform remnant

Count of flakes without platform remnant
Count of flakes without platform remnant and having dorsal cortex
Mass (g) of flakes without platform remnant

Angular debris:

Mass (g) of angular debris caught in G0 size grade.
Mass (g) of angular debris passing through G0 size grade.

Tuff:

Mass (g) of tuff fragments

Our earlier research (cf. Bloomer and Ingbar 1992) relied on a library of data provided by Stan Ahler (1989b) and on additional data generated by our own experimental program. We developed three discriminant functions applied to each sample. The first determined statistically whether the sample was from core reduction, from tool edge retouch, or from biface reduction. Samples in the latter group then were assessed with a second discriminant function which statistically separated early biface thinning (Callahan's [1979] Stages 1 to mid-Stage 3) from late thinning and early to late thinning. A third discriminant function segregated late thinning from early/late thinning.

One outcome of the study was our suspicion that mass analysis results may vary with core form. Ahler's experimental reductions, made for the most part on thin tabular cobbles of Knife River Flint, may be inappropriate for Tosawihi opalite biface production due to constraints posed by each raw material. Opalite, for example, can occur in large blocks requiring removal of more than two-thirds of the block weight merely to initiate reduction (Elston 1992a). For the present project, we conducted additional experimental flintknapping and mass analysis of the resultant debris, contributing to a dataset that now consists of over 100 opalite reduction sequences. These data were used to generate new discriminant models for interpretation of Locality 36 debitage.

We sought a single discriminant function to segregate mass reduction (e.g., core reduction), initial bifacial edge preparation, early bifacial thinning, and late thinning. Each sample was assessed using the same descriptors employed in the technological analysis. We used only single technological class control cases, arrayed in Table 4, to generate the discriminant function. Table 5 presents the resulting discriminant function and associated statistics. Reclassification of the cases used to create the discriminant function (i.e., post-hoc classification) shows that the accuracy of the function is greatest with late thinning (80% correct classification) and least accurate with early thinning (40% correct classification). Overall, reclassification yielded approximately 65% correct classifications. Examination of the misclassified cases shows that initial edging samples often were classified incorrectly as early thinning; conversely, misclassified early thinning samples most often were classified initial edging, an outcome suggesting considerable analytical similarity between the two groups.

Table 4. Summary of Experimental Opalite Reduction Sequences Employed in Generating the Mass Analysis Discriminant Function.

	TECHNOLOGICAL CLASSIFICATION*			
	M (n=3)	B (n=30)	E (n=5)	L (n=5)
G0 count (s.d.)	6 (9)	1 (2)	0 (0)	0 (0)
G0 mass (s.d.)	729 (1130)	63 (161)	0 (0)	0 (0)
G1 count (s.d.)	30 (28)	11 (10)	13 (8)	2 (2)
G1 mass (s.d.)	930 (1086)	180 (181)	187 (107)	21 (37)
G2 count (s.d.)	66 (68)	36 (27)	55 (40)	15 (13)
G2 mass (s.d.)	223 (243)	105 (68)	157 (119)	23 (23)
G3 count (s.d.)	217 (226)	148 (112)	213 (138)	165 (154)
G3 mass (s.d.)	78 (79)	50 (36)	75 (45)	19 (11)

*Technological characterizations: M = mass reduction; B = initial biface edging (Stage 2); E = Early bifacial thinning (to mid-Stage 3); L = late bifacial thinning (after mid-Stage 3).

Table 5. Discriminant Function.

a. Fisher's Linear Discriminant Function Coefficients.

Variable	Function 1	Function 2	Function 3	Function 4
MeanG3Wt	63.08	58.53	67.05	15.50
PerWtG3	50.59	34.73	37.82	57.75
PerCtG0	-756.17	-415.95	-528.73	-443.82
PerCtG2	117.35	77.15	80.56	93.80
WtG1G3	6.58	3.69	4.25	4.39
CtG1G3	-189.51	-114.04	-131.35	-116.97
Constant	-44.12	-23.28	-27.96	-24.41

Variables: MeanG3Wt = mean weight of G3 debitage; PerWtG3 = proportion of total mass in G3 size grade; PerCtG2 = proportion of total frequency in G0 size grade; PerCtG2 = proportion of total frequency in G2 size grade; G1G3Wt = mass in G1 size grade divided by mass in G3 size grade; CtG1G3 = frequency in G1 size grade divided by frequency in G3 size grade.

b. Post-hoc classification.

		Predicted Group Membership			
Actual Group	n	M	B	E	L
M (mass reduction)	3	2 66.7%	0 0%	1 33.3%	0 0%
B (initial edging)	30	1 3.3%	20 66.7%	8 26.7%	1 3.3%
E (early thinning)	5	0 0%	3 60.0%	2 40.0%	0 0%
L (late thinning)	5	0 0%	1 20.0%	0 0%	4 80.0%

To examine the accuracy of the discriminant function in greater detail, we tabulated all other experimental cases against their predicted classification (Table 6). These experimental cases are not individual technological stage samples, so they may fall correctly into more than one discriminant classification and still be considered "correct" in some sense. As Table 6 shows, within this loose definition of correct classification, the discriminant function worked fairly well. However, this points out a failing of the approach as a whole, whereby classification fails to take range of variation into account. We shall return to this.

Table 6. Discriminant Function Classification of Experimental Multi-stage Debitage Assemblages.

Actual Stages	Mass red.	Predicted Stage Initial Edging	Early thinning	Late thinning	% "correct"
mass reduction and initial edging	5	1	0	0	100%
initial edging and early thinning	3	14	6	2	80%
initial edging, early thinning, slight amount of late thinning	1	12	2	0	93%
initial edging, early thinning, and late thinning	0	4	2	2	100%
early thinning, slight amount of late thinning	0	0	1	0	100%
early and late thinning	0	0	1	0	100%

Shading indicates "correct" classification.

Another approach to the interpretation of mass analysis has been proposed by Stahle and Dunn (1982, 1984). Using a nested set of ten sieves ranging from 2 in. to 1/8 in. to size-grade debitage generated by experimental small patterned biface production, they showed how the resulting cumulative density functions of mass and frequency within size grades fit a Weibull distribution function. Weibull distributions are similar to logarithmic distributions (in fact2, the latter is a special case of the former). Weibull transformation of the experimental cumulative density functions for different stages of biface production produced linear plots of the transformed variates against the natural logarithm of sieve size. Stahle and Dunn used the transformed (linear) cumulative density functions to calculate linear regressions for each biface stage. The regressions were statistically distinct for each. Because most archaeological samples are expected to be mixtures of reduction stages, Stahle and Dunn then showed how these data can be used to solve a "mixture" model by the method of constrained least squares. Although they were successful in determining the percentage contributions of different reduction stages to mixtures of their own experimental data, Stahle and Dunn (1984:34) noted

> In view of the many factors that could potentially affect prehistoric flake size data from biface reduction, a conservative approach to the interpretation of flake size analysis is recommended. Although constrained least squares analysis will assign a specific percentage to each stage present in an unknown flake assemblage, strict interpretation of these percentages could be misleading. Instead, the simple identification of initial, middle, final, or some combination of these stages would be both cautious and adequate for most archaeological purposes.

We modified the Stahle and Dunn approach in analyzing the mass debitage data from Locality 36, both to evaluate the discriminant model and to asses whether it could portray sample variation. Cumulative density functions were calculated for staged experimental reductions made on flake blanks and on block cores. Variates for each of four mesh sizes then were transformed using a Weibull transformation (cf. Stahle and Dunn 1984:11-12) and were plotted against the natural logarithm of mesh size. Figure 30 shows the resulting plots for mass and frequency for pooled replications in each of the four technological stages used in attribute analysis. Later reduction stages occur above earlier ones. We then plotted some multiple stage experimental cases against these values; these fell in intuitively sensible positions.

Encouraged by these results, we then plotted two archaeological samples, already examined by technological analysis, against the same experimental data. The archaeological cases plotted somewhat earlier than we thought they should, given our knowledge of the samples (Figure 31). The positions of archaeological sample curves show them similar to mass reduction assemblages. One likely reason is the inclusion in our control cases of replications made on flake blanks. Flake blank biface production yields less debitage than biface production on block cores. Consequently, we revised our control curves, retaining the data on late biface thinning of flake blanks, since by the time biface production reaches this stage the shape is independent of initial form. For earlier stages, we used multi-stage replications (mass reduction and initial edging; initial edging, and early biface thinning) made on block cores. Figure 32 shows one of the same archaeological specimens plotted against this set of control cases.

Sample Selection

To insure that we examined a representative sample of debitage recovered from different contexts within Locality 36, we stratified the samples on the basis of context (cf. Chapter 3), and randomly selected (at varying percentages) actual samples for analysis.

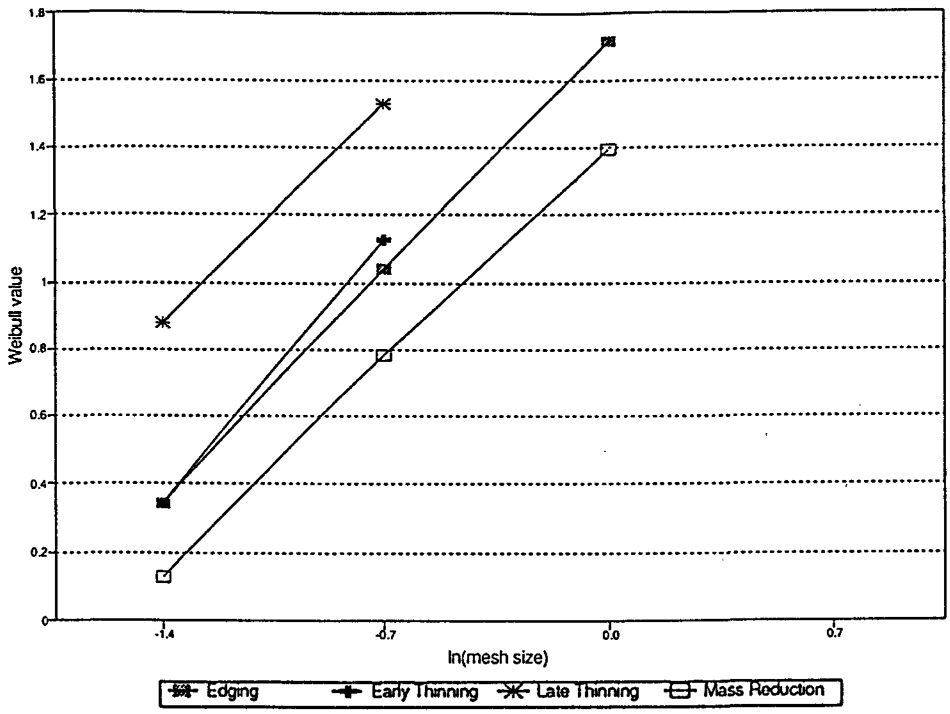
Surface Scrape Units

Five hundred sixty-two 25cm by 25cm surface scrapes (two per 10m by 10m grid square) were sorted into angular debris, platform bearing flakes, and non-platform-bearing flakes. Each category then was counted and weighed, but not size-graded. All samples then were analyzed technologically. Because some surface scrapes yielded no debitage, 486 samples resulted.

Transects Through Features

Transects through Features 42, 49, and 79, consisting of 50cm by 50cm surface scrapes at 1 m intervals, were sampled at 50% intensity. No units from Feature 22 were analyzed. Samples were subjected to the regular mass analysis sorting and size-grading protocol described above; selected samples then were analyzed technologically.

a



b

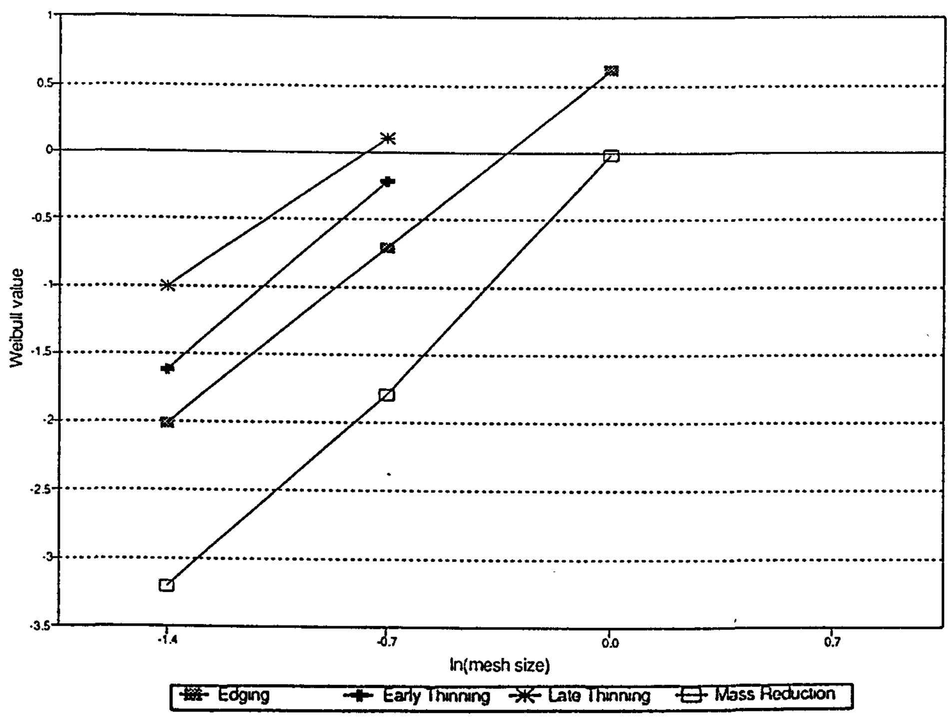
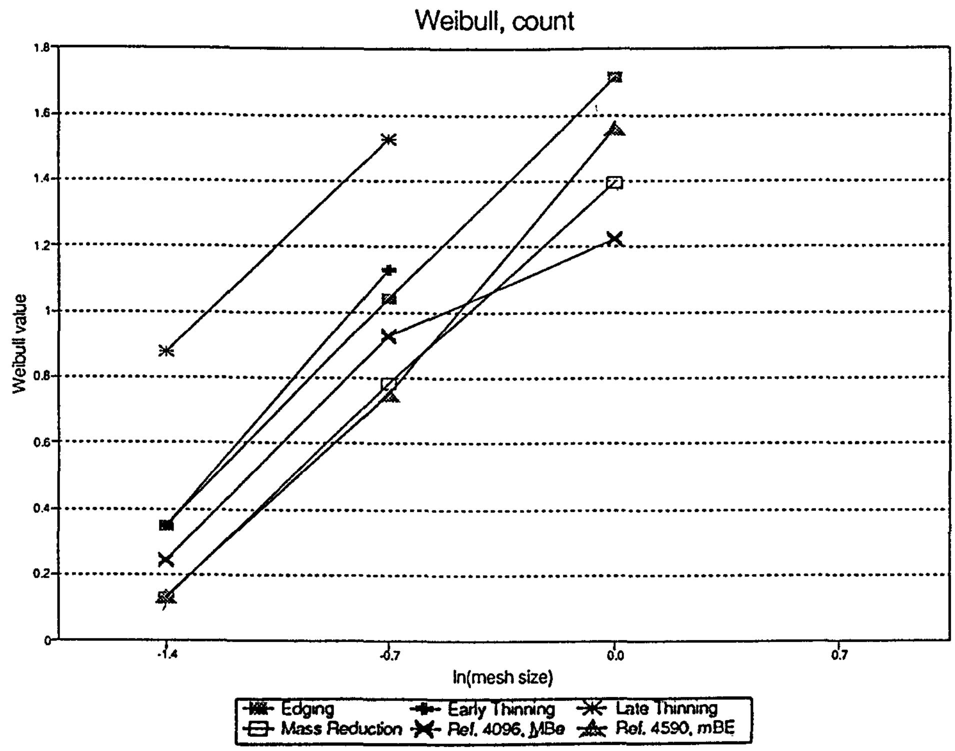


Figure 30. Plots of Weibull-transformed values of experimental debitage assemblages: a. based on counts; b. based on weights.



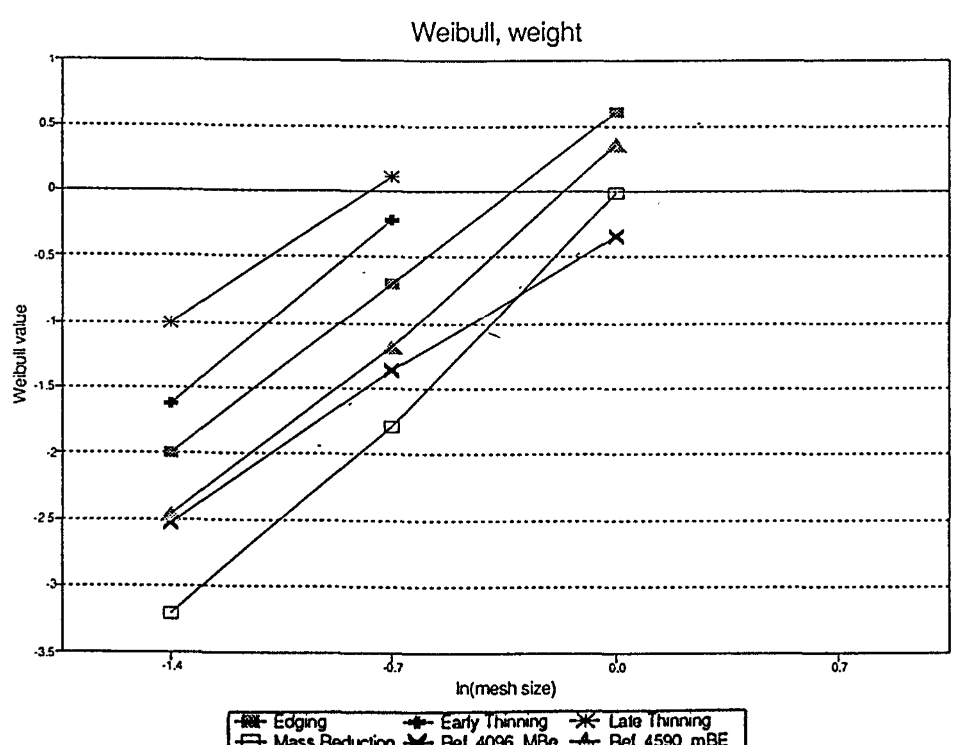


Figure 31. Plots of Weibull-transformed values of experimental debitage assemblages and two archaeological debitage assemblages.

Feature 6 Address 510 Level 0 Sample 4590.1

Mass Analysis Summary (PRB + non-PRB totals)

g0 count	g0 mass (g)	g1 count	g1 mass (g)	g2 count	g2 mass (g)	g3 count	g3 mass (g)	total mass (g)	total count	angular debris mass (g)
2	210.7	26	435.0	46	159.3	158	71.2	876.2	232	44.5

Mass Analysis Statistical Result — Mass Reduction

Technological Analysis Result — mBE

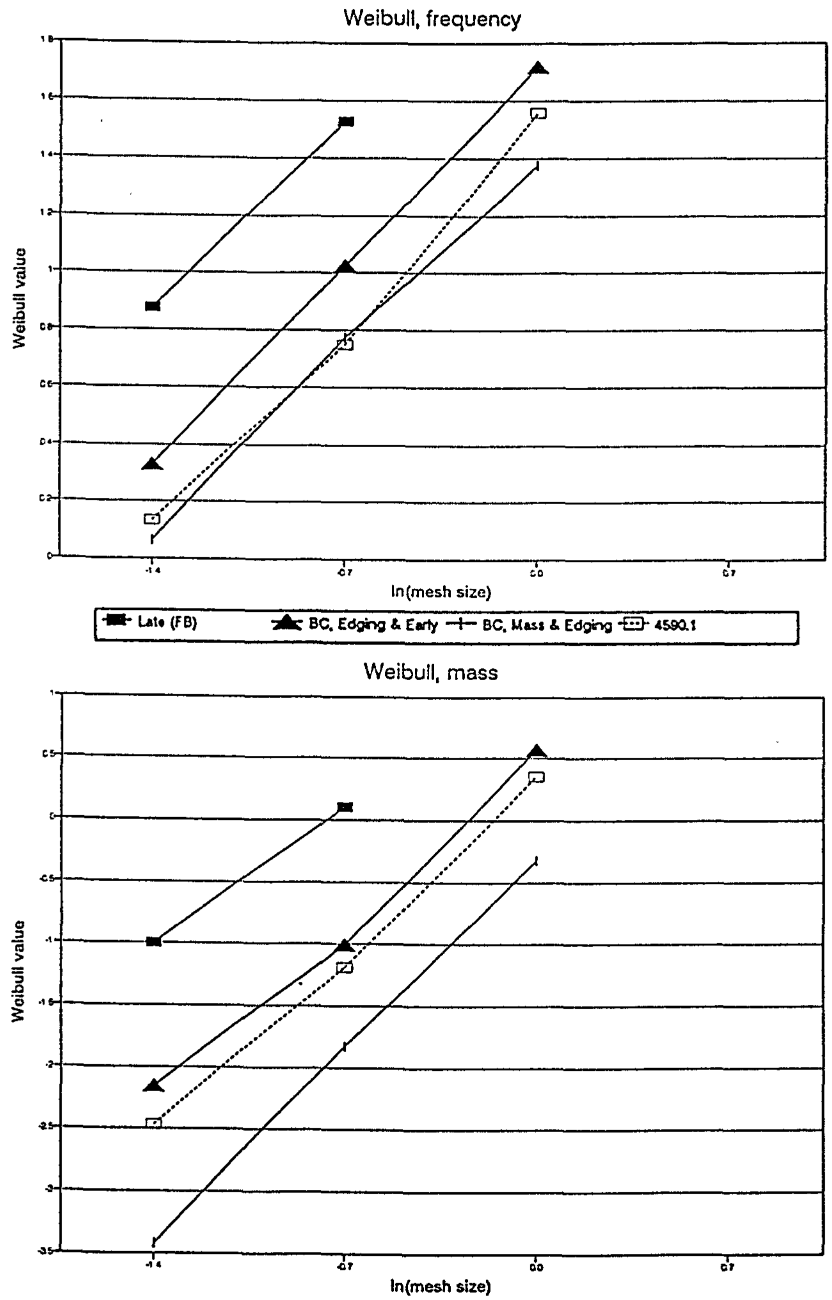


Figure 32. Example of Weibull analysis worksheet for archaeological debitage assemblages.

Reduction Feature Excavation Units

Excavation units in lithic reduction features yielded two sample portions for each unit: a surface sample (0-2 cm depth) and everything lying below. For every feature chosen for analysis half the excavation units within it were analyzed. So, for each selected unit, both the 0-2 cm and deeper levels were examined through mass analysis. The selected samples were analyzed using the usual mass analysis sorting and size-grading protocol. Selected feature samples then were examined by technological (typological) analysis.

Feature 102 Excavation Units

Three excavation units were placed along Trench 3 to sample older deposits. We selected two of these for analysis. All debitage from each level was analyzed using both the usual mass analysis sorting and size-grading, and technological (typological) analysis.

Excavation Units Associated with Buried Features

In addition to units in Feature 102, scraping by a road grader uncovered several other features (Features 105 to 110) central to the site (cf. Chapter 3). All debitage from excavation units on or adjacent these features was sorted, counted, and weighed, but not size-graded.

Inter-feature Excavation Units

Five excavation units were placed haphazardly between areas of surface features (Units 583 to 587). Samples from these were not analyzed.

Lithic Inventories of Trench Strata

We performed a technological analysis in the field, during the recording of quarry pit trenches. Notes on the exercise were converted easily into our system of notation for technological analyses performed in the laboratory; witness samples were not subjected to mass analysis.

Analytical Results

The general results of analyses are discussed in the following order: technological analysis, mass analysis using a discriminant model, and mass analysis using Weibull models. After presenting these results, we compare them. There follows a general summary of debitage evidence.

The debitage analysis data from specific contexts or specific areas of Locality 36 are used to examine other research issues elsewhere in this report. Consequently, not *all* the data are presented in this section; for example, counts and weights of debitage from the 562 random cluster sample surface scrapes are not discussed. Appendix A gives the analytical data discussed here.

Technological Analysis

Three hundred nineteen debitage samples were examined through technological observation. Sample selection was non-random; 65 samples consist of debitage from the random cluster sample surface scrapes, selected in approximately equal proportions from three groups: those with high total flake weights and low flake frequencies, those with low total flake weights and high flake frequencies, and those with relatively high weights and frequencies. A fourth potential group (low weight, low frequency) is too small for meaningful characterization. In addition, 176 debitage samples were selected from various feature contexts including reduction features, hearths, quarry pits (both surface scrapes and trench strata), and non-feature excavation units. Of these, 10 were too small to be characterized reliably. Finally, 88 additional samples were characterized in the field during examination of trench strata. Thus, among 319 samples studied, 221 were examined in their entirety.

The frequency of technologically analyzed samples from various site contexts is shown in Table 7. Samples from quarry pits or units immediately adjacent them are most frequent, followed closely by those from reduction features. Samples without feature association comprise the third most frequent class, and hearth or possible hearth settings, the least. Frequencies are presented in Table 8.

Table 7. Archaeological Contexts of Technologically Analyzed Samples (n=319).

Context	n	%
No feature association	65	20.4
Flake scatter/reduction feature	114	35.7
Hearth/possible hearth	18	5.6
Quarry pit/adjacent quarry pit	122	38.2
Total	319	100.0

Because sample selection was not random, frequencies are not directly interpretable in probabilistic terms. Nonetheless, they illustrate the overall range of variation in Locality 36 debitage, and they *roughly* reflect how frequently different reduction categories occur. The six most frequent characterizations (B*EL, MBE, QM, QMB, QMBE, and mBE) occur in approximately equal frequencies, and jointly comprise 39% of the total. These indicate the major reduction activities at Locality 36. Quarrying of opalite blocks and reduction of their mass clearly were important, as were blank preparation and early thinning. Late thinning of opalite bifaces was infrequent.

Table 8. Technological Analysis, Frequencies of Categorizations (n=319).

Technological Characterization	n	% of total	Technological Characterization	n	% of total
B	4	1.3	Q*Me	2	0.6
B*	1	0.3	Q*mBE	1	0.3
B*E	3	0.9	Q*mbE	1	0.3
B*EL	1	0.3	QEl	1	0.3
BE	16	5.0	QM	23	7.2
BE*	3	0.9	QM	L	0.3
BE*l	2	0.6	QM E	5	1.6
BEL	1	0.3	QM EL	1	0.3
BEL*	2	0.6	QM e	3	0.9
BEl	3	0.9	QM*B*E	1	0.3
C* E	1	0.3	QM*BE	1	0.3
C*mel	1	0.3	QM*BEl	2	0.6
E	3	0.9	QM*Be	1	0.3
EL	2	0.6	QM*b	1	0.3
El	1	0.3	QM*bE	1	0.3
L	1	0.3	QMB	15	4.7
M	7	2.2	QMB L	2	0.6
M E	2	0.6	QMBE	19	6.0
M*B*El	1	0.3	QMBE*	1	0.3
M*B*e	1	0.3	QMBE*L	2	0.6
M*BE	4	1.3	QMBE*l	1	0.3
M*BEl	1	0.3	QMBEL	3	0.9
M*Be	3	0.9	QMBEl	1	0.3
M*bE	3	0.9	QMBe	2	0.6
M*bEl	1	0.3	QMb	1	0.3
M*be	1	0.3	QMbe	3	0.9
MB	3	0.9	QmB*E*l	1	0.3
MB*E	3	0.9	b	2	0.6
MB*E*l	2	0.6	b L	1	0.3
MB*El	1	0.3	bE 109	1	0.3
MB*e	1	0.3	bEL	2	0.6
MBE	14	4.4	be	1	0.3
MBE*	3	0.9	e	1	0.3
MBEL*	1	0.3	m E	1	0.3
MBEl	2	0.6	mB	1	0.3
MBe	9	2.8	mB L	1	0.3
ME	1	0.3	mB*	1	0.3
Mb	2	0.6	mB*E	1	0.3
Mbe	1	0.3	mB*e	2	0.6
Q*	2	0.6	mBE	11	3.4
Q* E	1	0.3	mBE*	2	0.6
Q* El	1	0.3	mBE*l	2	0.6
Q* e	1	0.3	mBEL	1	0.3
Q* BE	1	0.3	mBEl	1	0.3
Q*M	12	3.8	mbE	1	0.3
Q*M E	4	1.3	mbE*	1	0.3
Q*M e	7	2.2	q BE	1	0.3
Q*M*be	2	0.6	qM*B*e	1	0.3
Q*MB	2	0.6	qM*BE	2	0.6
Q*MBE	10	3.1	qM*Be	1	0.3
Q*MBEl	1	0.3	qMB*E	1	0.3
Q*MBe	6	1.9	qMBE	1	0.3
Q*MBel	1	0.3	qMBE*l	1	0.3
Q*ME	3	0.9	qMBe	2	0.6
Q*MEl	1	0.3	qMbE*	2	0.6
Q*Mb	3	0.9	qmB*E*	1	0.3
Q*MbE	2	0.6	qmBE	1	0.3
Q*Mbe	3	0.9	TOTAL	319	100.0

KEY: Q =Quarrying Debris
M = Mass Reduction Debitage
B = Blank Reduction Debitage
E = Early Biface Thinning Debitage
L = Late Biface Thinning Debitage

Lowercase = Trace Quantity
Capitalized = Frequent
Capitalized with asterisk following = Dominant

When the frequency of each category of reduction is tabulated, a pattern of initial processing emerges (Table 9). Mass reduction, blank preparation, and early biface thinning are the most frequent kinds of reduction, occurring in at least trace amounts in 70% to 80% of the samples examined. Furthermore, they are important or dominant technological characterizations in 50% to 60% of all samples. Late bifacial thinning occurs in only 16% of the examined samples; quarry debris appears in only 38%, and is important or dominant only in 30% of the samples.

Table 9. Frequency of Single Technological Characterizations (n=319).

Category	n	% of total
Q*	67	21.0
Q	92	28.8
q	14	4.4
Subtotal	173	54.2
M*	28	8.8
M		162.4
m	33	10.3
Subtotal	260	81.5
B*		23.2
B	171	53.6
b	36	11.3
Subtotal		72.1
E*		24.5
E	153	48.0
e	56	17.6
Subtotal	233	73.0
L*		0.9
L	19	6.0
l	29	9.1
Subtotal	51	16.0

KEY: Q = Quarrying Debris; B = Blank Reduction Debitage; E = Early Biface Thinning Debitage; L = Late Biface Thinning Debitage; Lowercase = Trace Quantity; M = Mass Reduction Debitage; Capitalized = Frequent; Capitalized with following asterisk = Dominant

The moderate frequency of quarry debris and the low frequency of late bifacial thinning characterizations probably have separate causes. Late bifacial thinning is genuinely rare at Locality 36. On the other hand, the moderate incidence of quarrying debris is a result of our sample set; approximately 40% of our samples are from quarry pits or immediately adjacent them. Quarry debris is rare in other contexts; only two samples with quarry debris are from reduction features. So, quarry debris appears in the sample set proportionate to the number of samples from or near quarry features.

When samples from quarry pits are tabulated separately (Table 10), the robustness of this pattern is apparent. Not surprisingly, over 90% of the samples from quarry pit contexts reflect quarrying and mass reduction. The high frequency of blank preparation and early biface thinning is somewhat surprising, since one might expect these to occur away from quarry features. Other Tosawihi quarries exhibit much lower incidences of blank preparation and early biface thinning than Locality 36 (Table 11), which is distinguished by its high incidence of early biface thinning in quarry pit contexts.

Table 10. Frequency of Single Technological Characterizations, Samples in or Adjacent Quarry Pits Only (n=122).

Category	n	% of total
Q*	67	54.9
Q	36	29.5
q	8	6.6
Subtotal	111	91.0
M*	15	12.3
M		92.4
m	9	7.4
Subtotal	116	95.1
B*		5.7
B	52	42.6
b	21	17.2
Subtotal	80	65.6
E*		10.2
E	51	41.8
e	37	30.3
Subtotal	98	80.3
L*		0.0
L	3	2.5
l	12	9.8
Subtotal	15	12.3

KEY: Q = Quarrying Debris; B = Blank Reduction Debitage; E = Early Biface Thinning Debitage; L = Late Biface Thinning Debitage; Lowercase = Trace Quantity; M = Mass Reduction Debitage; Capitalized = Frequent; Capitalized with following asterisk = Dominant

Table 11. Comparison of Debitage Characterizations from Quarry Sites in the Tosawihi Vicinity.

Debitage Characterization	Loc. 36 n=122	Loc. 26 n=32	Loc. 23 n=34	26Ek3200 n=12	26Ek3208 n=66	26Ek3084 n=18
Mass Reduction	116	25	23	9	64	12
% of n	95.1	78.1	67.6	75.0	97.0	66.7
Blank preparation	80	15	32	10	46	8
% of n	65.6	46.9	94.1	83.3	69.7	44.4
Early thinning	98	10	9	2	4	0
% of n	80.3	31.3	26.5	16.7	6.1	0.0

Only samples from quarry pits or adjacent to them are tabulated. Locality 26 data from Leach and Botkin (1991). Data on additional sites taken from Bloomer and Ingbar (1992).

Technological categorizations also can be used to examine how often reduction was continuous, as well as to identify the articulations of interrupted sequences. For example, if extraction and mass reduction are performed in one setting and the resulting block taken elsewhere for blank preparation and thinning, the reduction sequence at the first location will be "QM" and at the second, "BE." To examine this in the archaeological samples, the frequency of each (continuous) sequence was tallied (Table 12). The resulting tallies demonstrate that among assemblages beginning with either mass reduction or blank preparation, the most frequent terminus was early stage thinning (i.e., the biface itself was initially thinned). The sequence frequencies for samples with quarrying debris are more complicated, exhibiting this same trend (reduction through early thinning), but also a second mode consisting only of quarry and mass reduction debris. In summary, the continuity of reduction sequences indicates that early thinning of bifaces was a common endpoint of reduction regardless of starting point. A second, shorter sequence consisting of toolstone extraction and mass reduction also is common.

Table 12. Frequency of Starting and Ending Points of Continuous Sequences.

Sequence	n	
Q	8	Quarry only
QM	62	Quarry and mass reduction
QMB	24	Quarrying through blank preparation
QMBE	66	Quarrying through early thinning
QMBEL	13	Quarrying through late thinning
M	13	Mass reduction only
MB	8	Mass reduction and blank preparation
MBE	61	Mass reduction through early thinning
MBEL	13	Mass reduction through late thinning
B	8	Blank preparation only
BE	24	Blank preparation and early thinning
BEL	11	Blank preparation through late thinning
E	5	Early thinning only
EL	3	Early and late thinning
L	1	Late thinning only

KEY: Q = Quarrying Debris; B = Blank Reduction Debitage; E = Early Biface Thinning Debitage; L = Late Biface Thinning Debitage; Lowercase = Trace Quantity; M = Mass Reduction Debitage; Capitalized = Frequent; Capitalized with following asterisk = Dominant

Mass Analysis

One hundred fifty-six samples were sorted, size-graded, weighed, and counted using the protocol described earlier for "full" mass analysis. Seventy samples contained fewer than fifty pieces of debitage; these were excluded from further consideration, since in such small samples a miscounted item makes at least a 2% difference in proportions (cf. Bloomer and Ingbar 1992). The remaining 86 samples were analyzed using both a discriminant function classification and the Weibull comparison techniques already described. We first discuss the sample contexts, then present the results of the two techniques.

The sample set was drawn randomly from two contexts: quarry pit areas and flake scatters. Samples were selected in equal numbers from each context, but valid samples (n greater than or equal to 50) are only in approximate parity (Table 13).

Table 13. Contexts of Mass Analyzed Samples.

Context	Total n	Total %	Valid n	Valid %
Flake Scatter/ Reduction Feature	78	50.0	38	44.2
Quarry Pit/ Adjacent Quarry Pit	78	50.0	48	55.8
Total	156		86	

The discriminant model procedure already presented (cf. Table 5) was used to classify the samples; Table 14 summarizes the results. Mass reduction and early biface thinning dominate. Only three samples were classified as blank preparation. These results clearly are at odds with those from technological analysis (Table 9). We shall return to this soon.

Table 14. Summary of Mass Analysis Results, Discriminant Classifications.

Discriminant Model Mass Analysis Characterization	n	% of Valid Sample (n=86)
Mass Reduction	44	51.2
Blank Preparation	3	3.5
Early Biface Thinning	39	45.3
Late Biface Thinning	0	0.0
Not Analyzed, n50	70	81.4

The same 86 samples also were classified by plotting them against the Weibull distributions of our replications (cf. Figure 32). We next examined plots of individual replications to calibrate our interpretations. Then we characterized each sample by contrasting the plots of mass and frequency distributions. Each sample was summarized using a notation similar to that employed in the technological analysis, differing only in the lack of a "dominant" notation for each category (e.g., "M*" in Table 9). This technique lacks the numeracy of the least-squares regression employed by Stahle and Dunn (1982, 1984), but we think it appropriate for these data. Table 15 presents the frequencies of the resulting characterizations. The three most frequent characterizations (BE, BEl, MBe) together account for more than half the sample. Overall, results are similar to those from technological analysis. Differences lie partly in the more frequent characterization of trace amounts of late bifacial thinning in the Weibull results, where quarrying by-products were not an analytic category.

Table 15. Frequency of Technological Categories, Weibull Analyses (n=86).

Characterization of Weibull Plot	n	% of total
BE	18	22.2
BEL	1	1.2
BEl	13	16.0
El	2	2.5
MB	8	9.9
MBE	8	9.9
MBe	14	17.3
Q	1	1.2
QMb	2	2.5
mBE	8	9.9
qMB	5	6.2
qMBE	1	1.2
Total	81	100.0

KEY: Q = Quarrying Debris; M = Mass Reduction Debitage; B = Blank Reduction Debitage; E = Early Biface Thinning Debitage; L = Late Biface Thinning Debitage; Lowercase = Trace Quantity; Capitalized = Frequent

When the sample results are considered in terms of the frequency of individual characterizations (Table 16), as presented above for the technological analysis, blank preparation and early biface thinning are clearly the dominant reduction stages; mass reduction is a distant third, and late bifacial thinning is relatively infrequent.

Table 16. Frequency of Individual Characterizations, Weibull Analyzed Samples (n=86).

Category	n	% of total
Q	3	3.5
q	6	7.0
Subtotal	9	10.5
M		[illegible].2
m	8	9.3
Subtotal	46	53.5
B	76	88.4
b	2	2.3
Subtotal	78	90.7
E	70	81.4
e	14	16.3
Subtotal	84	97.7
L	1	1.2
l	15	17.4
Subtotal	16	18.6

KEY: Q = Quarrying Debris; B = Blank Reduction Debitage; E = Early Biface Thinning Debitage; L = Late Biface Thinning Debitage; Lowercase = Trace Quantity; M = Mass Reduction Debitage; Capitalized = Frequent; Capitalized with following asterisk = Dominant

Comparison of Techniques and General Synopsis

Some mass analysis results, particularly those from discriminant classification, are at odds with the characterizations made in technological analysis. For example, Tables 9 and 14 reflect very dissimilar characterizations of the same debitage. On the other hand, the Weibull results and technological analysis results are *relatively* similar. Characterizations of the Weibull plots suggest less mass reduction, more blank preparation, and more early biface thinning than the technological analysis. They do not detect quarry reduction at all, since it was not included in the control cases. Which analysis is correct? Why do they differ? Reasons for differences in the analytical techniques are discussed here, contrasting the results for each sample set and technique.

Two issues merit consideration. First, Locality 36 provides an opportunity to evaluate archaeological methods themselves. The technical challenge presented by the sheer volume of material in quarries can be met only by active development of efficient analytical techniques. Comparison of the three analyses used in this project is a step in this direction. Second, to determine what was produced at and transported from Locality 36 requires evaluation of the accuracy of the different debitage analysis techniques.

Mass Analysis Discriminant Modeling

The discriminant function classification of mass-analyzed debitage assemblages does not fit well with either the Weibull characterizations or the technological analysis results (compare Tables 8, 9, 14, 15, and 16). The discriminant results (cf. Table 14) suggest a much later debitage assemblage at Locality 36 than either of the other techniques. Furthermore, blank preparation is hardly visible in the discriminant classifications, but as a single technological category it was found in 72% of the technologically analyzed samples and in over 90% of the Weibull characterized samples.

Accepting, for the moment, that the results of technological analysis are more likely correct than the discriminant classification of mass analysis data, no consistent pattern of misclassification can be discerned (Table 17). Samples characterized by technological analysis as dominated by one reduction type (e.g., "M*") do not fall consistently within their correct—or nearly correct—categories. Several explanations are possible: (1) poor control cases may have been used to build the discriminant function, (2) the resulting functions themselves have poor discriminatory power, or (3) the archaeological samples "violate" assumptions inherent in the discriminant approach, contradicting the logic of discriminant modelling.

The use of inappropriate control cases certainly would affect the accuracy of the resulting discriminant functions. Inappropriate cases are those that differ so greatly in start point, end point, or technological process from prehistoric production that they constitute feeble analogs. We believe the dataset used in creating discriminant functions to be innocent of this failure. Rather, we attempted to reproduce the technological strategies observed in Tosawihi archaeology. Another inappropriate control case derives from inaccurate recording owing either to imprecise work or to unrecognized bias. This also seems improbable, since we analyzed experimental debitage assemblages precisely as we did the archaeological ones. In fact, during analysis, we recorded many experimental assemblages employing all three techniques without reference to the start and end points of the experimental samples.

Table 17. Cross-Tabulation of Mass Analysis Discriminant Classification with Technological Analysis Characterizations.

Technological Characterization	Discriminant Classification: Mass Reduction	Blank Preparation	Early Thinning	Total
B*E	-	-	1	1
B*EL	-	-	1	1
BE	-	1	4	5
BEl	-	-	1	1
M	1	-	-	1
M*B*e	1	-	-	1
M*BE	2	-	-	2
M*BEl	-	-	1	1
M*Be	-	1	-	1
M*bE	2	-	1	3
M*bEl	1	-	-	1
M*be	-	-	1	1
MB	1	-	-	1
MBE	4	-	-	4
MBE*	1	-	-	1
MBEL*	1	-	-	1
MBEl	-	-	1	1
MBe	1	-	-	1
Q*M*be	1	-	-	1
Q*MBE	2	-	1	3
Q*Mbe	-	-	1	1
Q*mBE	-	-	1	1
Q*mbE	-	-	1	1
QM*Be	1	-	-	1
QM*b	1	-	-	1
QM*bE	1	-	-	1
QMB	-	-	1	1
QMBE	1	-	1	2
QMBE*	1	-	-	1
QMBE*l	1	-	-	1
QMBe	-	-	1	1
QMbe	1	-	2	3
b L	1	-	-	1
bEL	-	-	1	1
m E	-	-	1	1
mB*e	1	-	-	1
mBE	5	-	1	6
mBE*	-	-	1	1
mBE*l	-	-	2	2
qM*B*e	1	-	-	1
qM*BE	-	-	1	1
qM*Be	1	-	-	1
qMBE*l	1	-	-	1
qMBe	1	-	1	2
qMbE*	1	-	1	2
qmBE	-	-	1	1
Total	37	2	30	69

KEY: Q = Quarrying Debris; B = Blank Reduction Debitage; E = Early Biface Thinning Debitage; L = Late Biface Thinning Debitage; Lowercase = Trace Quantity; M = Mass Reduction Debitage; Capitalized = Frequent; Capitalized with following asterisk = Dominant

Poor discriminatory power may have led to the mismatch of results found here. A discriminant solution's power lies in the robustness of the resulting functions. The most distinctive functions should describe axes orthogonal to each other in n-1 dimensional space, where n is the number of categories one wishes to discriminate. Alternatively, a single powerful function may segregate categories along a single axis, so that each category forms a clump of cases not overlapping others. This property commonly is measured by the eigenvalues and percent of variance explained by each discriminant function. The discriminant functions determined in this research are more of the latter type: 80% of the control case variance was explained by the first discriminant function. The orthogonality of the functions was not examined mathematically, but bivariate function plots produced during the discriminant analysis indicate they are only partially orthogonal. We already have commented on the relative accuracy of the discriminant functions in reclassification of the control cases (Table 6): clearly, the categories do not "clump" as one might hope. Thus, poor discriminating power may be an important component of the results achieved here. This may be inherent to debitage data, since Ahler (1986:Table 4.15) also found that the first function accounted for a high proportion of his control case variance.

The logic of discriminant analysis is problematic as well. It is used most successfully when there is good reason to believe that the control cases used to determine discriminant functions are structurally similar to the unknowns to be classified.

The problem is simple. If one were to build a discriminant function to segregate three species of iris using measurements of 100 plants from each species, discriminant functions would apply properly to measurements from individual plants, since for each of the three hundred control cases the measurements used are from single specimens. It would violate the logic of the procedure, however, to reach then into a bag of unknown irises, take one measurement from the first, a different from the second, etc., and classify this composite case with the discriminant functions. Thus, discriminant analysis assumes that the domains of cases are similar. Inclusion of irises from still a fourth, unknown, species would create spurious results. The discriminant functions still would classify members of the fourth species as one of the three "known" species. Hence, effective use of discriminant analysis assumes (and requires) prior knowledge about unknown cases (allowing proper control cases to be chosen).

Regarding the latter assumption, our control cases (the experimental reductions) emulate the Tosawihi biface production trajectories as we understand them from prior research. The former assumption is more problematic, as it is, perhaps, in all archaeological studies. In essence, we must assume that the archaeological samples pertain to the same domain as experimental assemblages. But archaeological samples rarely are expected to be single events of reduction. Even if they are multiple events of the same *stage* of reduction, we lack sufficient knowledge of the effects of combining cases to be sure of the resulting outcome. In sum, archaeological applications of discriminant analysis *must* violate an important assumption of the discriminant process. No matter how well the analysis may reclassify unknown control cases, accuracy is unassured when the domains of unknown cases are likely to differ from the domain of control cases. We could, of course, have attempted to synthesize mixed assemblages from the experimental data, developing categories for these control cases. Yet, how would we have known what mixtures were appropriate? Any answer is circular.

Table 17 illustrates another problem. Technological analysis indicates that almost all the archaeological cases have several different stages of reduction. Even if the discriminant results more closely matched the technological characterizations, the resulting classifications would mask variation in each sample. The results would be accurate, but less informative than the technological characterizations.

In short, we are reluctant to recommend discriminant modelling in situations where a wide variety of debitage may have resulted from technologically different processes or reduction stages.

Mass Analysis Models of Weibull Distributions

To examine the efficacy of the Weibull transformation and characterization of the resulting curves, we compared the 64 samples analyzed by technological characterization and Weibull modelling (Table 18). These yielded generally similar results, except for detection of quarrying debris. Because no debitage assemblages resulting from quarrying were present in our experimental assemblages, we did not have a control curve for it. Hence it was interpreted from the Weibull plots for only two samples, both with curves that plotted lower than the Mass Reduction-Blank Preparation curve (cf. Figure 32).

Table 18. Cross-Tabulation of Weibull Analysis Characterizations and Technological Analysis Characterizations.

Technological Characterization	Weibull Characterization										
	QMb	QMB	QMBE	MB	MBE	MBe	BE	BEL	BEl	El	Total
B*E	-	-	-	-	-	-	-	-	1	-	1
B*EL	-	-	-	-	-	-	-	-	1	-	1
BE	-	-	-	-	-	-	1	-	-	-	1
M	-	-	-	-	1	-	-	-	-	-	1
M*B*e	-	1	-	-	-	-	-	-	-	-	1
M*BE	-	1	-	-	1	-	-	-	-	-	2
M*BEl	-	-	-	-	1	-	-	-	-	-	1
M*Be	-	-	-	-	-	1	-	-	-	-	1
M*bE	1	-	-	1	-	-	1	-	-	-	3
M*bEl	-	-	-	1	-	-	-	-	-	-	1
M*be	-	-	-	-	-	-	-	-	1	-	1
MB	-	1	-	-	-	-	-	-	-	-	1
MBE	-	-	-	-	1	1	2	-	-	-	4
MBE*	-	-	-	1	-	-	-	-	-	-	1
MBEL*	-	-	-	-	1	-	-	-	-	-	1
MBEl	-	-	-	-	-	-	-	-	1	-	1
MBe	1	-	-	-	-	-	-	-	-	-	1
Q*M*be	-	-	-	1	-	-	-	-	-	-	1
Q*MBE	-	-	-	-	-	1	1	-	1	-	3
Q*Mbe	-	-	-	-	-	-	1	-	-	-	1
Q*mBE	-	-	-	-	-	-	-	-	-	1	1
Q*mbE	-	-	-	-	-	-	-	-	1	-	1
QM*Be	-	-	-	-	-	1	-	-	-	-	1
QM*b	-	-	-	-	-	1	-	-	-	-	1
QM*bE	-	-	-	-	1	-	-	-	-	-	1
QMB	-	-	-	-	-	-	1	-	-	-	1
QMBE	-	-	-	-	1	-	1	-	-	-	2
QMBE*	-	-	-	-	1	-	-	-	-	-	1
QMBE*l	-	-	-	-	-	1	-	-	-	-	1
QMBe	-	-	-	-	-	-	1	-	-	-	1
QMbe	-	-	-	1	2	-	-	-	-	-	3
b L	-	-	-	-	-	1	-	-	-	-	1
bEL	-	-	-	-	-	-	1	-	-	-	1
m E	-	-	-	-	-	-	-	-	-	1	1
mB*e	-	-	-	-	1	-	-	-	-	-	1
mBE	-	1	-	-	2	2	-	-	1	-	6
mBE*	-	-	-	-	-	-	-	-	1	-	1
mBE*l	-	-	-	-	-	-	-	1	1	-	2
qM*B*e	-	-	-	-	-	1	-	-	-	-	1
qM*BE	-	-	-	-	-	-	-	-	1	-	1
qM*Be	-	-	-	-	-	1	-	-	-	-	1
qMBE*l	-	-	-	-	1	-	-	-	-	-	1
qMBe	-	-	1	-	-	-	1	-	-	-	2
qMbE*	-	-	-	-	-	-	1	-	1	-	2
qmBE	-	-	-	-	1	-	-	-	-	-	1
Total	2	4	1	5	15	11	12	1	11	2	64

KEY: Q = Quarrying Debris; M = Mass Reduction Debitage; B = Blank Reduction Debitage; E = Early Biface Thinning Debitage; L = Late Biface Thinning Debitage; Lowercase = Trace Quantity; Capitalized = Frequent; Capitalized with Following Asterisk = Dominant

Close attention to Table 18 also reveals that the characterizations of the Weibull transformations tend to encompass a lesser range of reduction stages than do technological characterizations. Presuming, again, that the technological characterizations are correct, the Weibull process itself is less sensitive to mixtures of different stages of reduction, at least when applied as here. The cause of this is the process itself. Characterization of the Weibull curves afforded us considerable leeway in interpretation, but they still plot only in one position, just as in discriminant analysis a classification is of either one type or another. When samples from different reduction stages are combined, the resulting curve is elevated or depressed. Thus, there is no indication of range. Adding additional control cases to the Weibull plots may alleviate the problem to some extent, but it still leaves the question of sample domain, discussed above, unresolved.

Technological Analysis and Characterization

Our results suggest that of the three methods of analyzing reduction stage, technological analysis seems to be most effective, for several reasons. First, the analyst quickly can assess for himself whether samples are of similar domains. For example, it is relatively easy to distinguish mass reduction and early stage thinning debris. Second, the time commitment probably differs little from that of mass analysis, especially when large samples are analyzed. We were able to analyze technologically about ten samples per hour. Finding samples, removing them from bags, and rebagging them was the major time consumer in the analytical process. Third, during the process of scanning the analyst has an opportunity to see new facets of the reduction technology. This can be important in understanding a reduction technology. For example, during the course of this analysis we noticed that the incidence of bulb removal flakes is not uniform in samples having blank preparation; some of the older quarry pit strata contained these flakes more often than other settings. This prompted further examination of the bifaces from the site. In any case, the analytical process itself is open-ended, permitting the researcher to follow new lines of inquiry as they present themselves.

The unconstrained nature of the characterization has drawbacks too. It can be difficult to compare samples to each other, and to the work of other analysts. Technological analysis presumes some prior knowledge of the technology under investigation (as do the two other techniques used in our analysis). Lastly, scan-based technological analysis lacks the perceptible precision of strictly quantitative techniques. None of these problems is insurmountable. Comparison of samples still can be accomplished, as we have shown above in presenting our results. Comparison to the work of other analysts simply requires more communication among researchers and avoiding idiosyncratic levels of characterization. The presumption of prior knowledge does not differ in kind from formal analysis, and is unavoidable in any chipped stone analysis. Lastly, quantitative approaches are not necessarily more precise, as we have taken some pains to demonstrate. Yet, if quantification of technological analysis is a desired goal, it is relatively easy to tabulate flake types for quantitative models of lithic reduction (cf. Bloomer and Ingbar 1992). These will be subject to the same problems of sample domain discussed above.

We found that size-graded samples (i.e., those already recorded by mass analysis) were somewhat easier to sort during technological analysis. In fact, there was a tendency for certain kinds of flakes to appear in particular size-grades. Quarrying debris almost invariably was trapped by the 2 inch sieve. Mass reduction flakes were caught mostly in the 1 inch and the 2 inch sieves. Blank preparation flakes often remained in the 1/2 inch sieve. Eliminating certain size-grades from technological analysis, as has been suggested (Moore 1991a), seems dangerous given these observations. Since recording the data necessary for the Weibull analysis is simple (consisting only of counting and weighing the flakes in each size-grade), we think studies of debitage assemblages probably should combine technological analysis with this simplified recording of mass analysis data.

Synopsis

The analysis of debitage can be used to address several questions. Although our answers to these sometimes are tentative, we address each of them in turn.

What was produced at Locality 36? Locality 36, like every other quarry locality at Tosawihi, appears to have been a source for material worked into bifaces. Almost all the debitage samples show evidence of biface production. Exceptions are the few samples containing only mass reduction or quarry debris. Some indications of biface size were noted during technological analysis. In the main, the bifaces produced at Locality 36 were of "average" Tosawihi size (approximately 8 cm to 12 cm in length), but flakes struck from larger bifaces also were found, particularly in Features 6 and 86. We estimate that some of the bifaces reduced in these features were at least 25 cm long.

What commonly was done with extracted opalite *at the locality*? Following extraction, opalite reduction at Locality 36 commonly included a stage of mass removal, followed by either flake blank production or initial preparation of block edges.

We found distinct evidence of the reduction of flake blanks into bifaces (i.e., the presence of bulb removal flakes) in many samples. The absence of bulb removal flakes in some samples neither confirms that block reduction occurred nor that flake blank reduction did *not* occur; rather, it is equivocal, since these are produced in low frequencies during flake blank reduction. However, the frequent occurrence of mass reduction debris suggests that bifaces also were commonly reduced directly from blocks of opalite.

Later phases of blank preparation—edge regularization—occurred commonly. Early bifacial thinning also was performed frequently. Evidence of heat-treatment is not abundant, but was present consistently in reduction features. When conducted, it usually was done sometime prior to (or during) the removal of early biface thinning flakes; many heat-treated flakes are early thinning flakes. Judging from the debitage, flake blank-based bifaces were heat-treated as well (though infrequently), but apparently at an earlier stage. In some samples we found evidence of heat-treatment before completion of blank preparation, associated with evidence of flake blank reduction. Overall, the incidence of heat-treatment observed at Locality 36 is much lower than at non-quarry sites in the Tosawihi vicinity (Elston and Raven 1992). This suggests spatial differentiation in the location of technological processes.

Bifaces were reduced infrequently, but not rarely, beyond early Stage 3. No evidence of the final finishing of biface edges was found. Based on the debitage alone, we estimate that bifaces were transported away from Locality 36 at the completion of or during Stage 3 early thinning.

Were activities other than opalite reduction performed at Locality 36? Very few pieces of debitage were recovered of materials other than locally available opalite. The few flakes of non-local raw material almost always were small flakes from facial reduction of stone tools or edge margin maintenance. This scant evidence suggests that *perhaps* a few activities other than opalite reduction occurred at Locality 36, but they were so infrequent and/or made so little use of stone tools that they left no concentrated areas of lithic debris.

Chapter 5

FLAKED STONE ARTIFACTS

Kathryn Ataman

This chapter describes the biface, flake tool, and projectile point assemblages recovered from Locality 36. The significant activities represented at the Locality focused on toolstone extraction and early stage biface production, and yielded many bifaces. Despite extensive excavations, the number of flake tools and projectile points recovered is limited, however, and reflects a narrow range of activities.

Failure and Rejection at Locality 36 : The Biface Assemblage

Most formed artifacts in the Locality 36 assemblage are bifaces; 635 complete and fragmentary bifaces were recovered. Most were abandoned early in reduction in or around quarry pits; only a few were finished sufficiently to serve as tools. The most striking aspect of these bifaces is that they represent an assemblage of manufacturing failures, many of them unbroken rejects, discarded for various reasons. This strongly influenced our analysis and interpretation.

Research Aims

Our analytical methods are those described by Ataman (1992). They are recapitulated briefly as the data are described and attributes of raw material, size, reduction stage, thermal alteration, breakage characteristics, and manufacturing techniques are examined.

Extrapolation from the unsuccessful to the successful product is central to our understanding of the Tosawihi biface production system. To extrapolate, we must consider other Tosawihi bifaces and make connections between them and those from Locality 36. Evidence for residential occupation of Locality 36 is scant, as it is at other (less intensively) examined quarry loci in 26Ek3032. Yet, extensive reduction of toolstone has been observed at campsites within a 12 km radius of the quarry center, suggesting that many of the bifaces produced at Locality 36 were transported to other sites in the vicinity, where they were reduced further before export from Tosawihi. This question will be examined through comparison of export products from Locality 36 and from previously investigated Tosawihi sites.

Bifaces broken in manufacture provide important information; when only finished objects are present, the manufacturing process is difficult or impossible to reconstruct. Observation of bifaces broken in various stages of manufacture, along with data from debitage studies, allows us to reconstruct production methods (Callahan 1979) and to identify reduction techniques that may be peculiar to specific features, sites, regions, or timeframes.

Throughout this chapter, comparisons will be made with assemblages analyzed during earlier research conducted in the Tosawihi vicinity (Elston and Raven 1992) from 1987 to 1989. A summary of these comparisons and more detailed comparison with specific quarry locations is presented later in the chapter. Like material from Locality 36, the earlier assemblage is composed primarily of rejects, but of ones discarded at a point much later into the reduction sequence and for different reasons.

Assemblage Description

Raw Material

Most bifaces recovered from Locality 36 are made of opalite; a very few are made of chalcedony and opal, varieties of opalite defined by degree of silicification. Tosawihi opalite can be recognized by its distinctive appearance under ultraviolet light (Elston 1992a) where it emits green light. While the ultraviolet scan technique is useful for identifying Tosawihi material recovered from non-Tosawihi contexts, presently it allows us to identify the presence of exotic materials. None were noted.

A small number of bifaces (n=4) are made of jasper, which does not outcrop at Locality 36. This material probably derives from either Locality 225 of 26Ek3032 or 26Ek3084, both nearby jasper quarries. In addition, there is a small number of opalite bifaces, the raw material of which clearly is of Tosawihi origin but from outside Locality 36. One, an early Stage 4 biface of green translucent opalite, probably is from the greater Tosawihi vicinity, considering that it glows green under ultraviolet light, but the material has not been noted in our previous studies. Another, made of distinctive salmon pink opalite (late Stage 3), probably derived from one or another of Localities 38, 39, and 48, all of which are within 300 m of Locality 36.

While the raw material outcropping at Locality 36 varies in texture, type, and number of inclusions, the color is quite uniform, ranging among grey, white, and beige. Approximately 97% percent of the assemblage exhibits these colors. Finely swirled and/or banded patterns appear in some of the material, much of which was recovered from contexts with early (ca. 4000 B.P.) ^{14}C dates. The presence of this distinctive opalite provides us a way to identify reduction activity relating to the earliest use of the quarry. The high proportion of bifaces made of the colors observed in the Locality 36 outcrops, and the swirled and banded patterning on some pieces in the assemblage, reinforce an impression that almost all the bifaces were derived from the raw material sources of Locality 36.

Size

Nearly 48% of the bifaces are complete and complete individual dimensions occasionally are preserved on broken pieces. For example, a piece missing only a tip still will retain its maximum width and thickness, although not its complete length or weight. In the interest of obtaining samples as large as possible, complete dimensions were recorded for each size variable (Table 19).

Table 19. Dimension Frequencies and Mean Dimensions of Bifaces.

	n with complete dimension	Mean	Standard Deviation
Complete Length	324	115.4 mm	26.1
Complete Width	429	74.1 mm	17.7
Complete Thickness	447	35.3 mm	12.1
Complete Weight	303	318.8 g	179.0

Most of the bifaces are failed, rejected specimens, and their proportions are likely to differ from successful products transported away from the quarry. Since there are so few Stage 1, Stage 4, or Stage 5 bifaces in the assemblage, only the sizes of Stage 2 and 3 bifaces are discussed here (the staging scheme is described in the following section). Recovered from an area closer to a material source than most bifaces in the earlier assemblage, Locality 36 bifaces are larger (Table 20). While only slightly longer (ca. 1 cm), width and thickness are substantially greater. Larger size and a high proportion of complete pieces indicates that these bifaces often were discarded because they could not be thinned successfully (Figures 33, 34). Thus, there is a significant difference between Locality 36 and the earlier assemblage, where only about 10% of the bifaces were complete and breakage was the main reason for biface discard.

Table 20. Comparison of Biface Sizes: 1987-1989 and Locality 36 Assemblages by Stage.

Stage		Length (mm)			Width (mm)			Thickness (mm)			Weight (g)			
		Mean	s.d.	CV	Mean	s.d.	CV	Mean	s.d.	CV	Mean	s.d.	CV	W/Th Ratio
Early 2	1987-1989	107	26.8	0.25	73.3	13.4	0.18	29.9	11.5	0.38	236.3	148.9	0.63	2.45
	Loc. 36	123.3	29.3	0.24	83.7	21.6	0.26	42.6	13.8	0.32	361	167	0.46	1.96
Late 2	1987-1989	110.6	28.7	0.26	69.2	17.8	0.26	38.2	12	0.31	258	218.5	0.85	2.45
	Loc. 36	115.7	16.1	0.14	78.7	16.8	0.21	39.1	11.5	0.29	351.5	180.3	0.51	2.01
Early 3	1987-1989	107	25.1	0.23	67.7	16.6	0.25	29.5	10.6	0.36	231.9	165.1	0.71	2.29
	Loc. 36	115.3	24.6	0.21	74.8	16.8	0.22	36.3	11.2	0.31	328.9	185.8	0.56	2.06
Middle 3	1987-1989	106.8	29.8	0.28	60	18	0.30	21.9	9	0.41	182.6	137.1	0.75	2.74
	Loc. 36	115.1	26.9	0.23	66.3	16.2	0.24	30.2	10.8	0.36	244.7	129.9	0.53	2.19
Late 3	1987-1989	108	36	0.33	50.7	17.8	0.35	14	5.7	0.41	128.2	88.4	0.69	3.6
	Loc. 36	107	27.7	0.26	61.9	14.6	0.24	20.7	6.3	0.30	246.7	-	-	2.99

There is little length difference between late Stage 2, early Stage 3, and middle Stage 3 bifaces, but width, thickness, and weight decrease through the reduction sequence while width/thickness ratios increase. Differences in width/thickness ratios, coupled with differences in the number of complete discarded specimens in both assemblages, again suggests that thinning failure at Locality 36 was one of the main reasons for discard. This point raises the issue of biface function to the extent that, if bifaces were intended primarily as cores, successful thinning would not be a primary factor in retention or discard decisions. Rather, bifaces with platforms and surfaces suitable for the detachment of flakes would be selected for retention.

Although the assemblage consists primarily of products rejected before their completion, consideration of size homogeneity allows us to evaluate whether biface production was oriented toward a standardized product(s) or toward variable ones. Standard deviation is the statistical

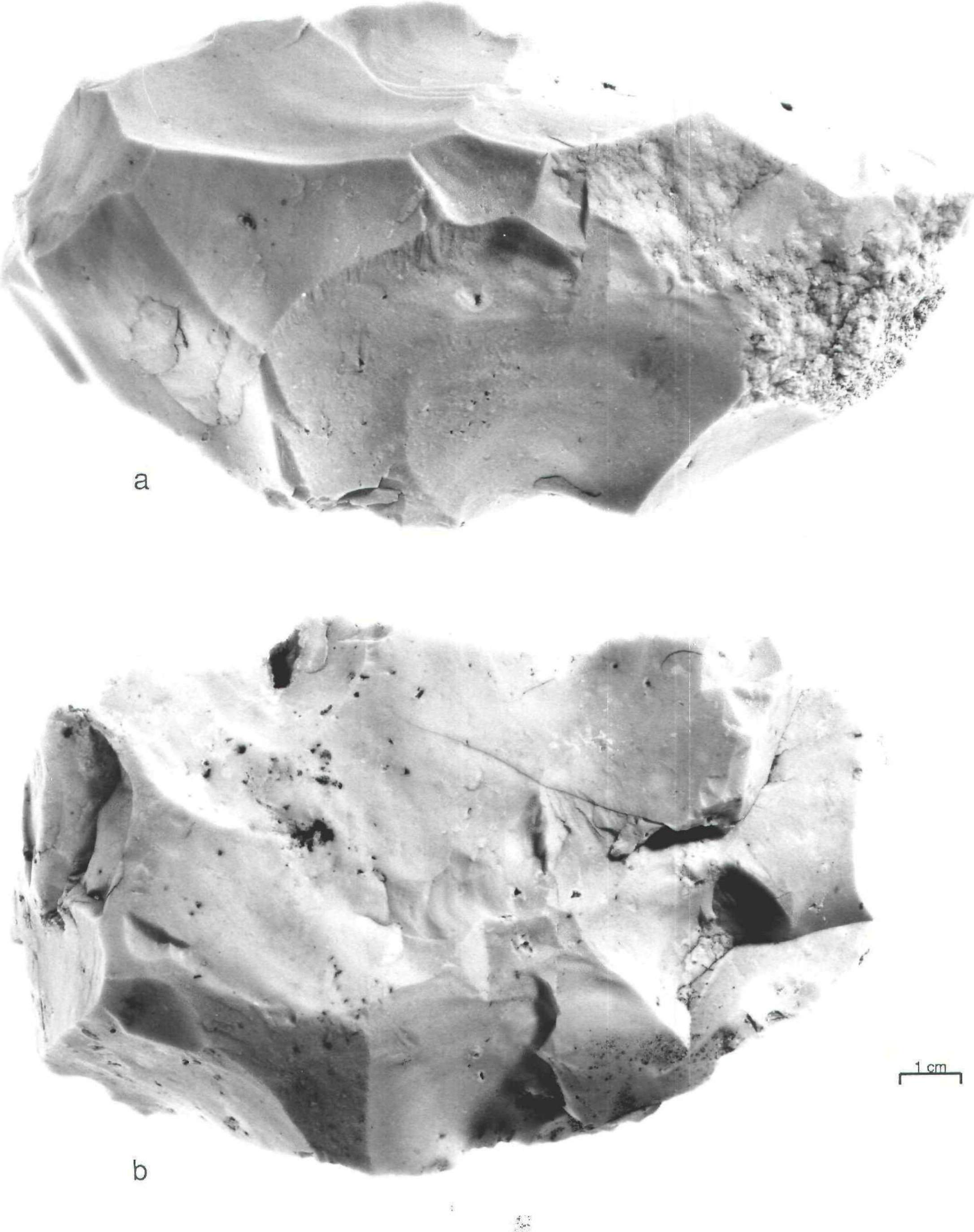


Figure 33. Complete bifaces discarded due to unsuccessful thinning.

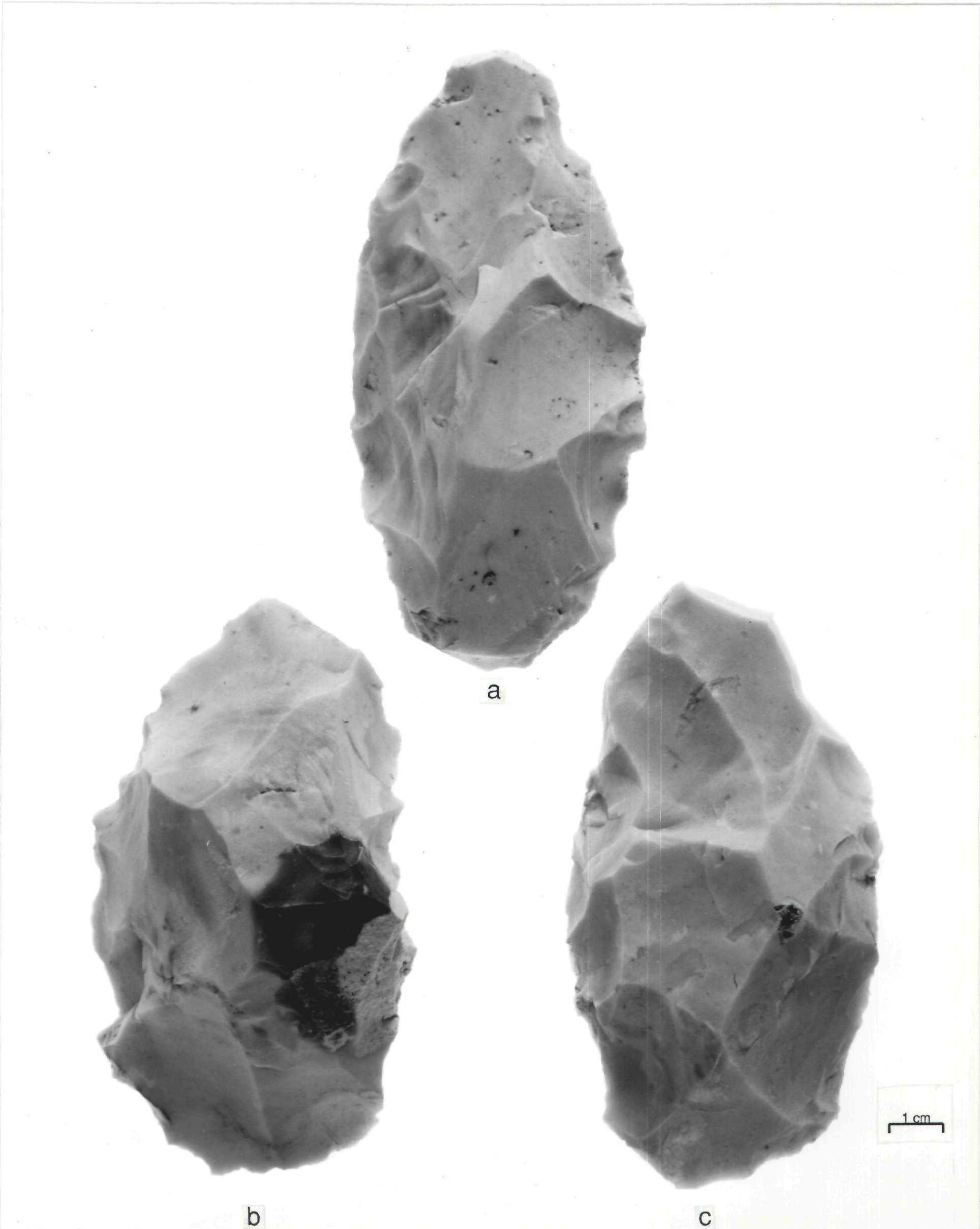


Figure 34. Bifaces discarded due to unsuccessful thinning.

measure of dispersion used most frequently, but comparison of standard deviations alone is misleading when, as in the present case, compared samples differ considerably. The coefficient of variation (CV) facilitates comparison of biface size using the standard deviation relative to the mean. A high value indicates greater variation. Table 20 presents means, standard deviations, and coefficients of variation for dimensions of complete bifaces at various reduction stages. Length and width exhibit fairly low variation (CV=0.21–0.26 and 0.14–0.26, respectively); thickness (CV=0.29–0.36) and weight (CV=0.46–0.56) are more variable.

When the assemblages are compared, in each dimension and in each stage, Locality 36 almost without exception has a lower coefficient of variation. This suggests that the product or products reduced at Locality 36 quarries are less variable in size (and, as we have noted above, are somewhat larger in most dimensions) than those reduced at previously investigated sites. This pattern, and the lower width/thickness ratios of Locality 36 bifaces, suggest that a single product was manufactured at the locality and that failure in thinning was the main reason for discard.

Reduction Stage

The reduction stages described here are based on Callahan's (1979) scheme for biface manufacturing. Variation in extent of reduction (flake scar patterning), cross-section, and width/thickness ratio all contribute to the determination of stage. The first stage consists of the unworked blank, the second of blank preparation and edge preparation, the third of primary thinning, the fourth of secondary thinning, and the final (Stage 5) of shaping and finishing. In our previous work at Tosawihi (Bloomer, Ataman, and Ingbar 1992), we subdivided Stages 2 and 4 into early and late, and Stage 3 into early, middle, and late in order to gain more detail about the organization of biface production. We use the same scheme here, but without subdivision of Stage 4.

The number of Stage 1 bifaces is very small, because, a Stage 1 biface, as defined, must have been selected for use in order to distinguish it from a rejected flake or block. At a source area it is impossible to recognize selected but unworked blanks, unless they are found in unusual contexts (e.g., caches). At Locality 36, bifaces were classified as Stage 1 only when they were observed outside direct quarry contexts. Only three such pieces were recovered (Table 21). Stage 4 and Stage 5 bifaces also are rare, reflecting the early nature of biface reduction at the quarry. Most of the assemblage consists of Stage 2 and Stage 3 bifaces.

Table 21. Biface Stages Represented in the Assemblage.

Stage	No.	%	% excluding indeterminate stage n=616
Stage 1	3	0.47	0.49
Early 2	31	4.90	5.00
Late 2	99	15.60	16.10
Early 3	343	54.00	55.70
Mid 3	107	16.80	17.40
Late 3	25	3.90	4.10
Stage 4	6	0.94	0.97
Stage 5	2	0.30	0.32
Indeterminate	19	3.00	-
Total	**635**	**100.00**	**100.00**

One complete, heat-treated Stage 5 specimen (two refitted pieces) appears to have been a finished tool (Figure 35e). Several sections of both edges appear to have been straightened with retouch and resharpening is evident in at least one area along the distal end of one lateral margin. At 100x magnification (using a light-incident metallurgical microscope), heavy rounding, probably indicative of use, is visible along 3 cm of one edge. This biface probably functioned as a cutting tool, but the material worked could not be determined nor is it known if the item once was hafted. Two other pieces, both distal ends of late stage bifaces (Figure 35a, b), were examined for use wear traces. Both exhibit some edge rounding and straightening, but use could not be established definitively.

Manufacturing Technology

Biface manufacturing attributes can indicate spatial or temporal differences in technology. Four technological features of bifaces are considered here: blank form, evidence of specialized reduction techniques, thermal alteration, and manufacturing failure. Each is discussed below, and the information is used in subsequent analyses to examine contextual differences.

Blank Form

Biface blanks may consist of flake blanks produced from a core or detached directly from bedrock, alluvial or colluvial cobbles, or blocks extracted from surface or subsurface bedrock. Flake blanks produced from cores and directly from bedrock can be morphologically similar, as is the debitage produced in their reduction, although bedrock-detached flake blanks more frequently exhibit straight profiles, wide platforms, and hinged terminations. The only positive evidence for flake blanks detached from bedrock is the negative flake scar on the bedrock (Figure 36).

In early stages of reduction, flake blanks can be recognized by characteristic features on the unworked portions of the ventral surface (Figure 37), such as point and cone of percussion, compression rings, and curved profile. Indirect evidence for the use of flakes as biface blanks includes the presence or absence of large cores in the assemblage. Because large cores can be worked into small ones, however, and cores can be worked directly into bifaces, a lack of cores is inconclusive evidence for the absence of flake-based biface reduction.

Use of quarried blocks for blanks is even more difficult to recognize. Unless a considerable portion of the original blank remains unworked (Figure 38), use of block blanks can be presumed only by reference to absence of cores, absence of flake blank produced bifaces, *and* absence of characteristic flake blank indicators in the debitage (i.e., presence of bulb removal flakes and alternate flakes or edge preparation flakes with original flake blank surfaces). Since recognition of block-based bifaces is problematic, flake blank bifaces here are contrasted with block and indeterminate bifaces combined.

At Locality 36, 13.7% of the bifaces exhibit characteristics suggesting their production on flake blanks (Table 22; cf. Figure 37). It is impossible however, to establish the precise frequency of the use of flake blanks because the evidence (visible on the ventral surface only) becomes obscured as reduction continues. In order to compare the sizes of flake blanks and block blanks in the assemblage, we first must eliminate the possibility that reduction stage influences that relationship. A chi-square test of this relationship (excluding Stage 4, Stage 5, and indeterminate stage bifaces) produces a value of 2.92 (df=5, prob. ca. 0.70), indicating no statistical association. Nevertheless, as seen in Table 22, flake blanks were noted more often among early stage bifaces. This allows us to compare directly the dimensions of flake and block based bifaces as a group.

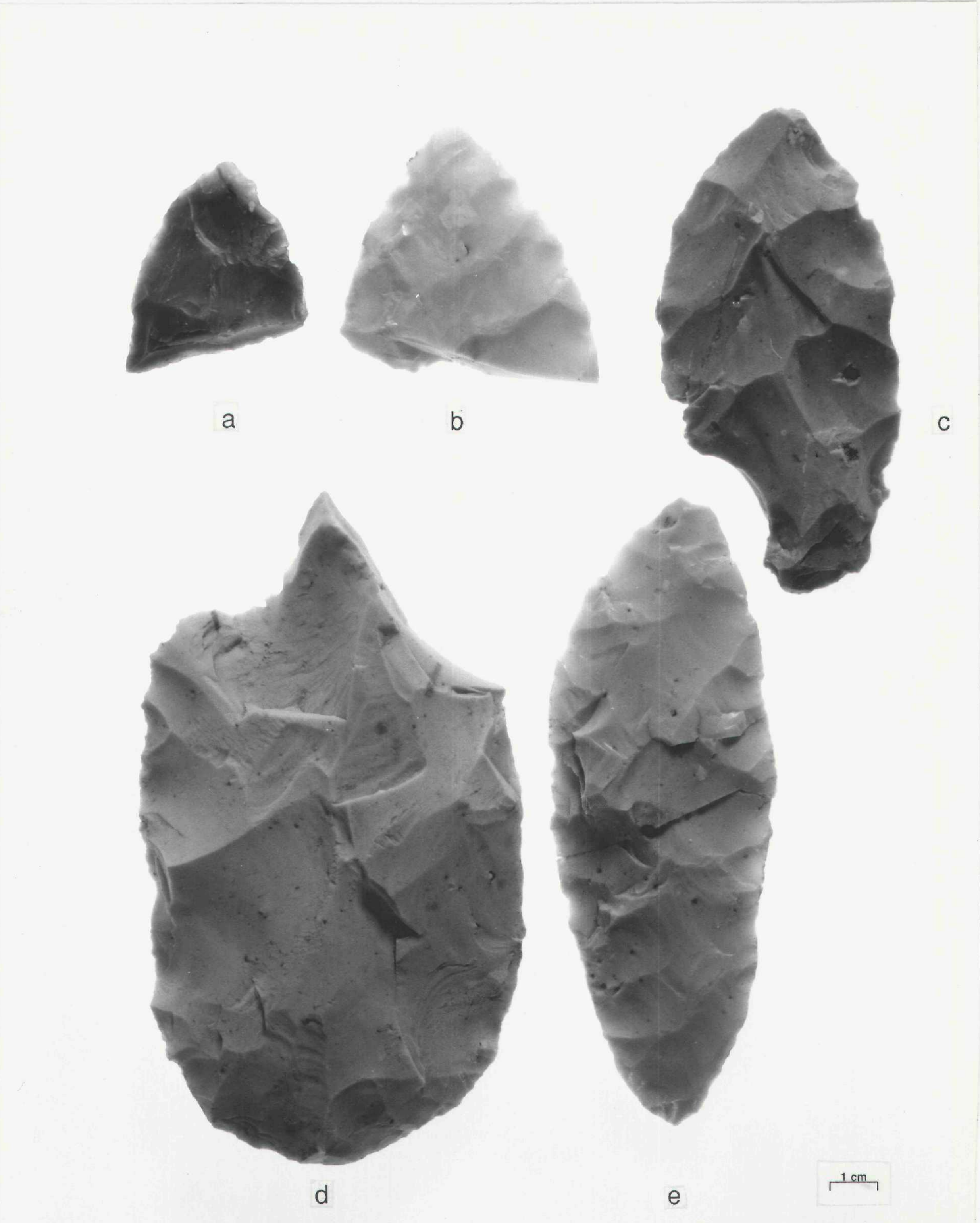


Figure 35. Successfully thinned bifaces.

Figure 36. Flake scar on bedrock outcrop.

Table 22. Bifaces from Flake Blanks by Reduction Stage.

Stage	no. made on flake blanks	% on flake blanks	no. on blocks or indet. blanks	% on blocks or indet. blanks	Total
1	1	33.3	2	66.3	3
Early 2	5	16.1	26	83.8	31
Late 2	21	21.2	78	78.8	99
Early 3	47	7.4	296	86.3	343
Mid 3	10	9.3	97	90.6	107
Late 3	1	4.0	24	96.0	25
4	1	16.7	5	83.3	6
5	1	50.0	1	50.0	2
Indeterminate	0	0.0	19	100.0	19
Total	87		548		635

The length, width, thickness, and weight of complete flake-produced bifaces and block and indeterminate bifaces were compared with t-tests. Differences in length were significant to $p=.002$, width to $p=.014$, and thickness and weight to $p<.000$. In each case, flake blank bifaces were smaller than the other two groups. Irregular blocks often require shaping before edging is feasible and the flakes produced in the course of shaping can be quite large. It is possible that flake blank bifaces were produced from early stage debitage produced in Stage 2 reduction, which would explain the presence of flake blank bifaces and absence of cores (cf. Chapter 4).

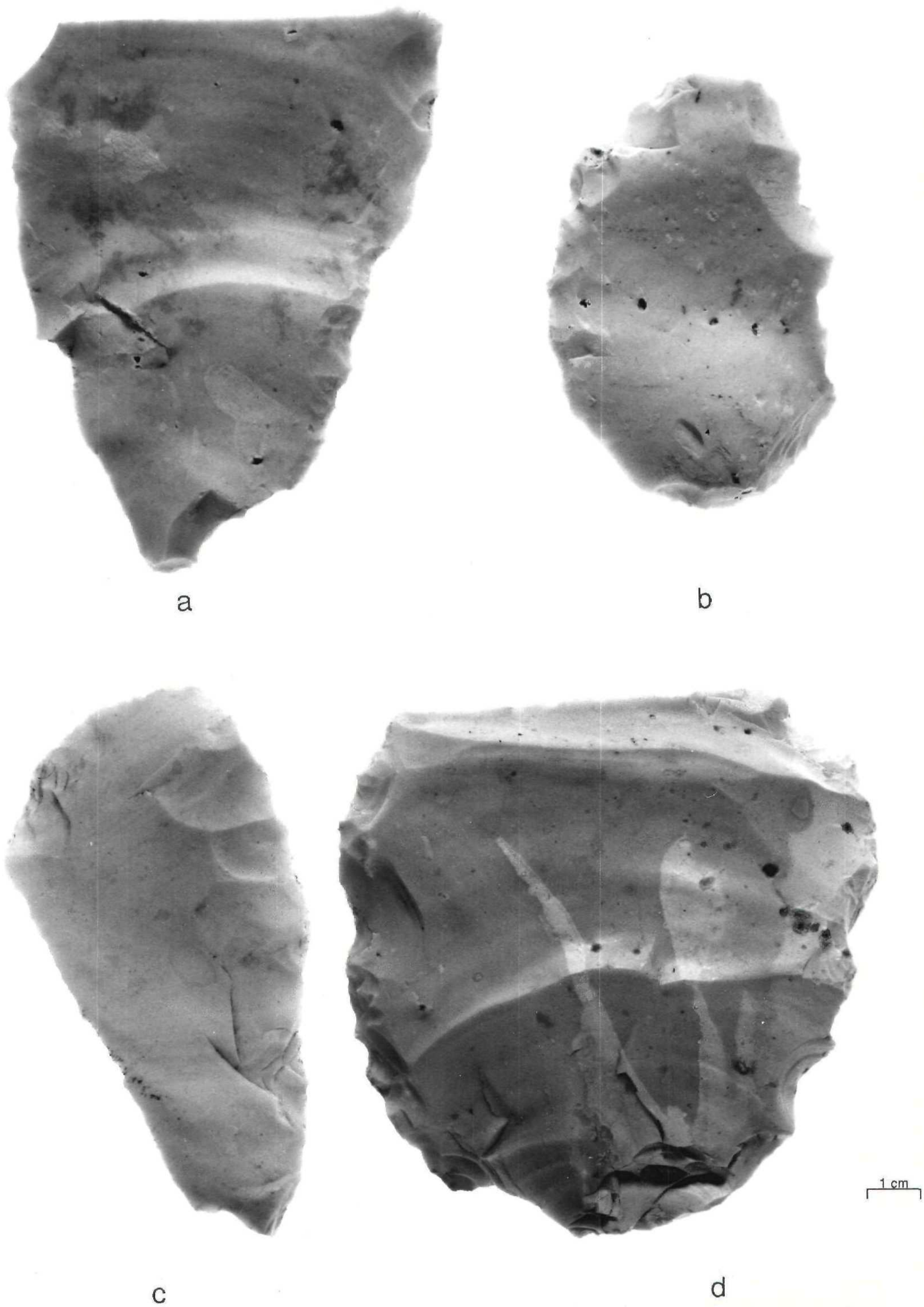


Figure 37. Selected flake blank-based bifaces.

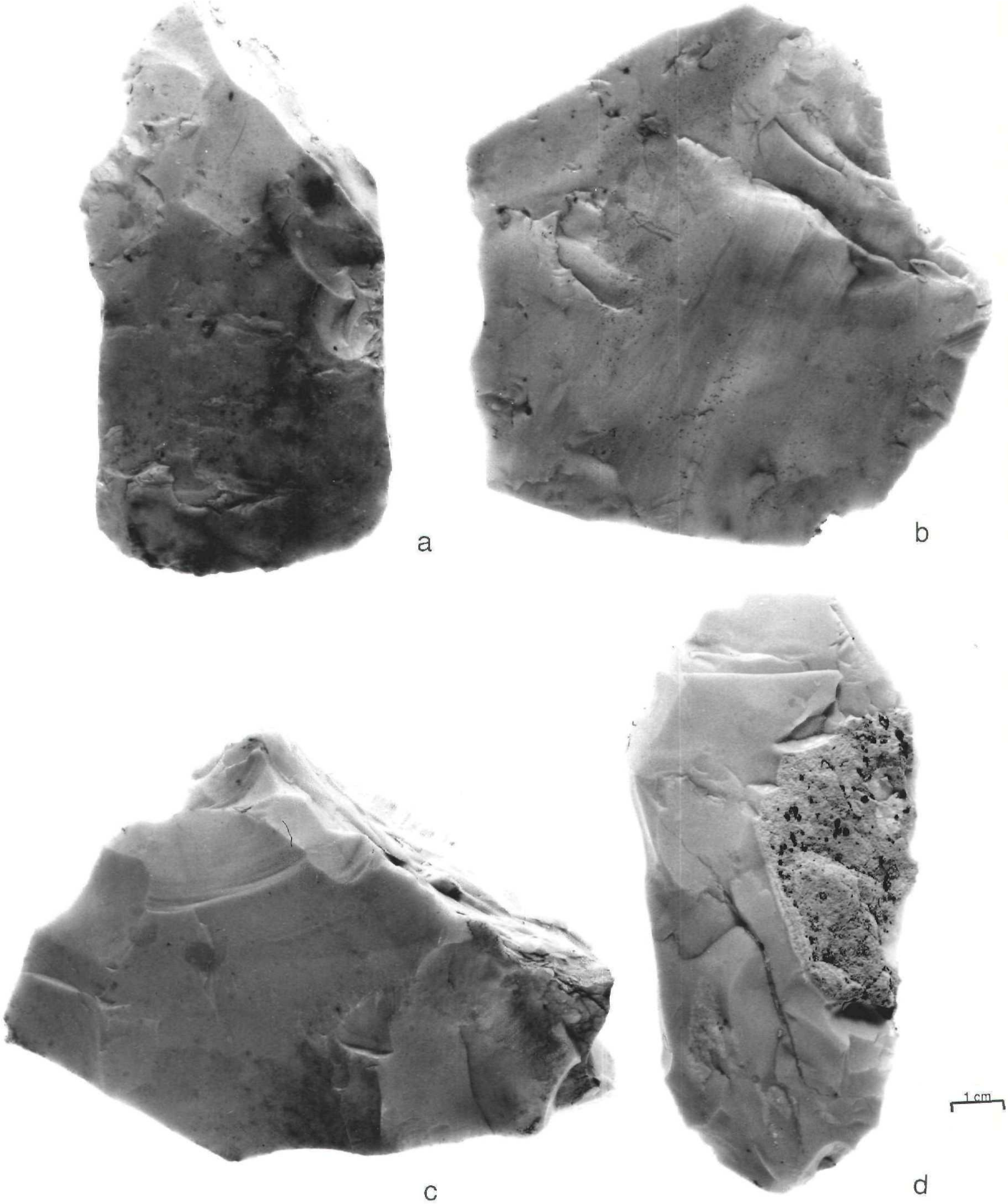


Figure 38. Selected block-based bifaces.

Specialized Reduction Techniques

Bifaces are among the most common formed artifacts in North American lithic assemblages, and they usually are produced in similar ways following a rather standard reduction sequence, even in different time periods or geographical areas. In this sequence, flakes are removed from an irregularly shaped blank to produce a lenticular form, and further reduction flattens the lenticular cross-section. Even within this generalized framework, however, reduction techniques specific to lithic industries may be employed that reflect temporal changes in technology or manufacture by groups that did *not* share a common technological tradition. In order examine the possibility that such patterns exist in the technology of biface production at Locality 36, we examined presence/absence, frequency, and distribution of several specialized techniques.

The use of four specific thinning techniques was examined in the course of analysis; two were selected because their presence had been noted in previous studies of Tosawihi bifaces (Bloomer, Ataman, and Ingbar 1992), while the others have been noted in other industries. Unifacial thinning of a square edge may have been developed to deal efficiently with the block blanks common at Tosawihi and at Locality 36 in particular, a form dictated primarily by the nature of the raw material deposits. End-thinning, outrepassé thinning, and the unifacial biface technique are less common at Locality 36, but, if their presence is restricted in time or space, changes in manufacturing strategies could be indicated.

Most often, thinning from a square edge is undertaken in Stage 2 reduction (blank preparation), although it has been noted when alternate flaking (edge preparation) and primary thinning (Stage 3) already had been initiated on another edge. Using this technique, mass is removed by means of a series of overlapping flake removals from the frequently right-angled edge of the blank prior to preparing an edge for bifacial thinning (Figure 39). Thinning from a square edge sometimes can be recognized on middle and late Stage 3 discards, but at Locality 36 most distinctive flake scars produced by use of this technique have been obscured by middle Stage 3.

Use of this technique was noted in a study of bifaces recovered from five caches in the Tosawihi vicinity (Moore 1992), suggesting it probably is relatively common in the assemblages from other Tosawihi sites. Fifteen percent of the total assemblage from Locality 36 exhibited evidence of thinning off square edges; the proportion was slightly higher among Stage 2 and early Stage 3 bifaces than among middle Stage 3 and later examples. No biface exhibiting this thinning technique had been heat-treated. Block-based bifaces often (41.9%) exhibit this technique, while flake blank produced bifaces were only rarely (5.7%) thinned in this way.

End-thinning is the second thinning technique examined in this analysis. It most often involves removal of a ridge running along the axis of the biface (Figure 40). Such ridges are set up by primary thinning in Stage 3, the distal ends of the negative scars forming the ridge. This technique is similar to "the Coso technique," whereby obsidian bifaces were thinned and biface blanks detached after setting up a central ridge. At Coso, however, the use of this technique was more frequent and the negative thinning scars covered much larger areas of the biface surface (Elston and Zeier 1984:Figure 21).

At Tosawihi, this technique may have been practiced as a last resort, when laterally oriented thinning was unsuccessful. Most end-thinning was practiced after initiation of primary thinning but before secondary thinning. Aside from being more risky to attempt in later reduction (hitting a biface on the end when it is relatively thin invites failure), the lenticular cross-section of a biface usually has been flattened by the end of primary thinning and there is little need for end-thinning. Six percent of bifaces at Locality 36 exhibit the use of this technique; two were heat-treated, and only five items exhibited both square edge and end-thinning.

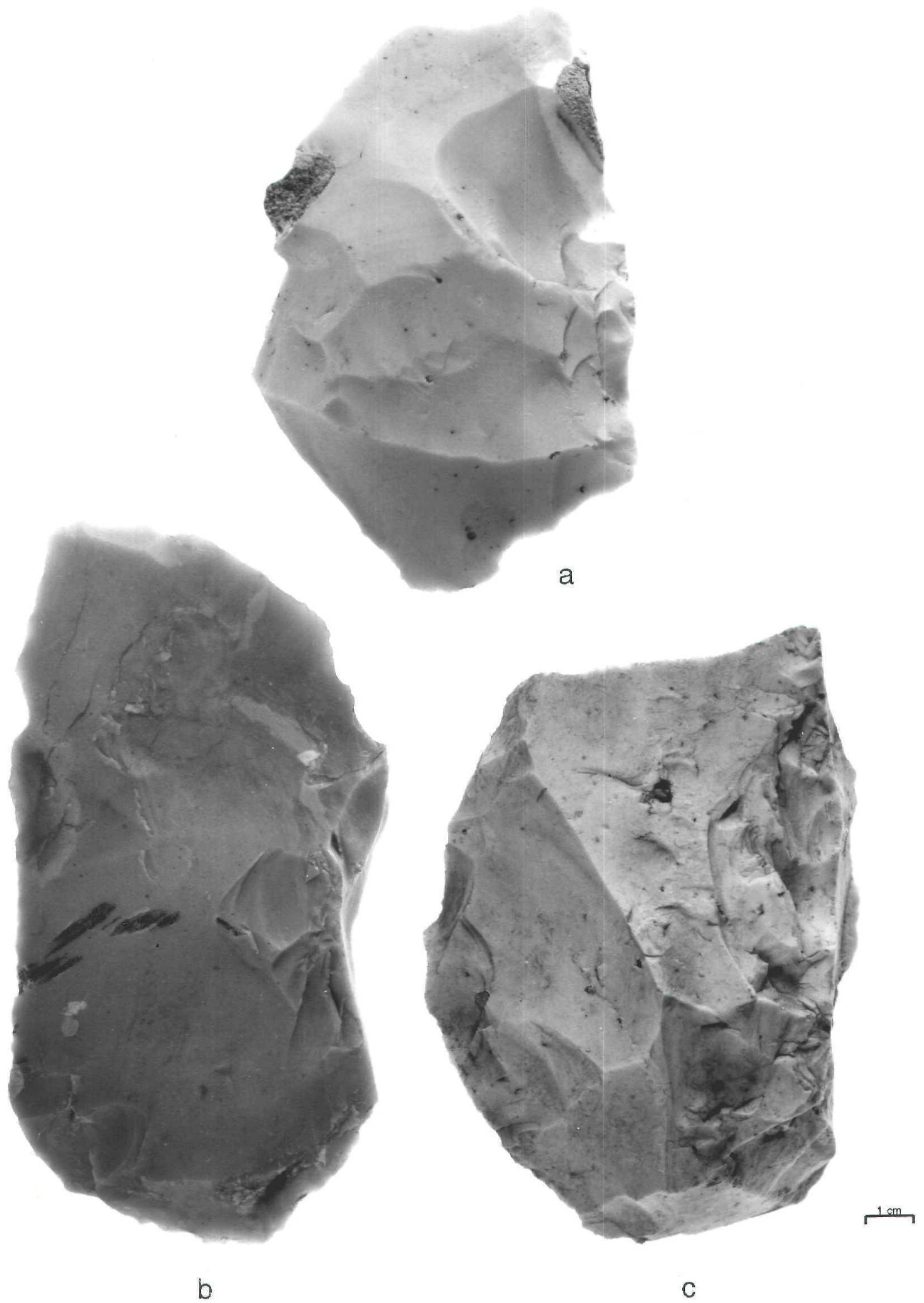


Figure 39. Bifaces exhibiting unifacial square edge thinning technique.

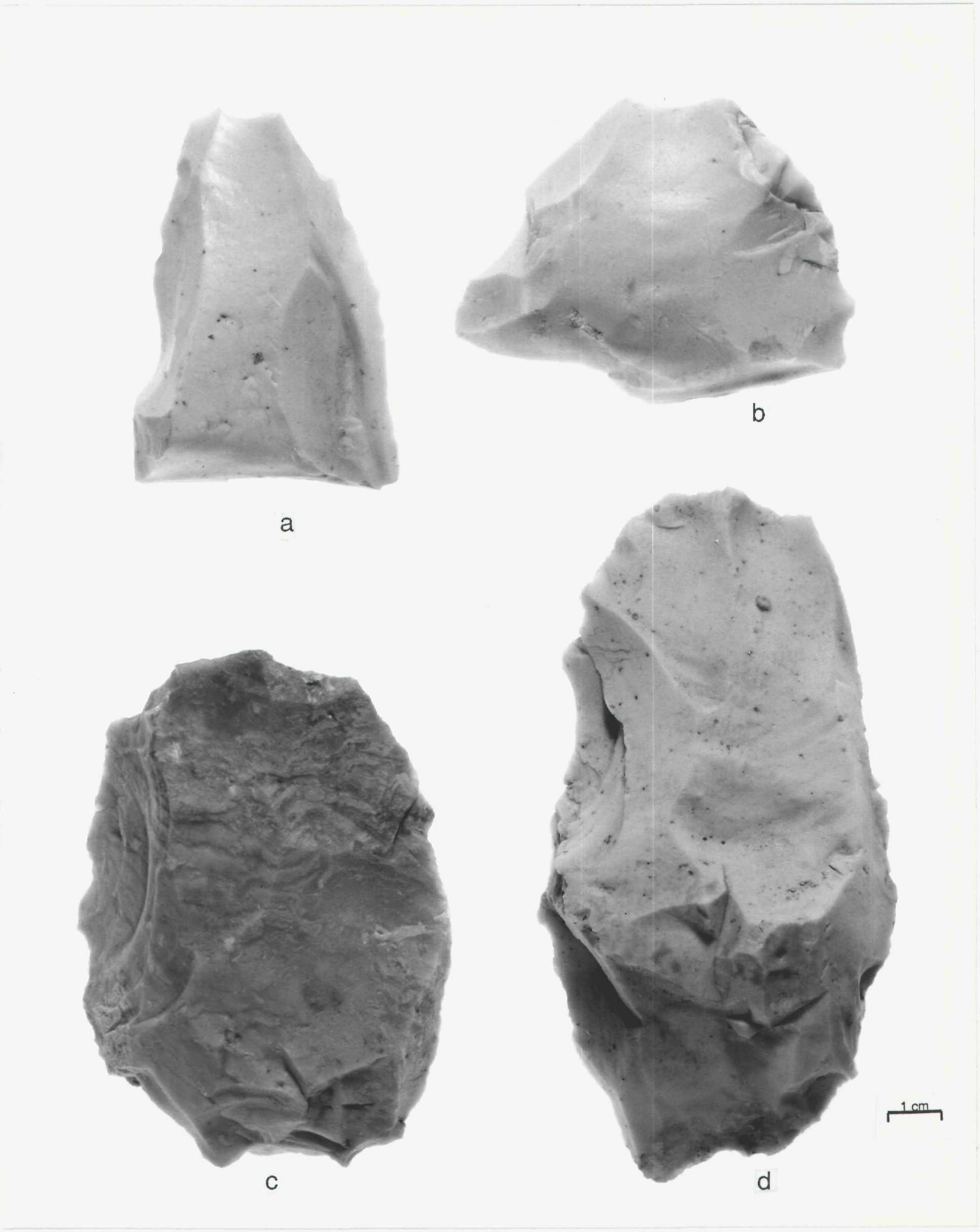


Figure 40. Bifaces exhibiting end-thinning technique.

Another specialized technique, deliberate use of lateral outrepassé flaking or overstriking to achieve biface thinning, has been noted by Bradley (1982) in a Folsom assemblage. Outrepassé flakes are produced by striking back from the edge of the platform at a right angle. Controlled use of this technique produces a wide, almost flat, negative scar, drastically thinning the face, but significantly narrowing the biface as well. Failure in end thinning often can result in a similar but longitudinally oriented outrepassé. The frequency of lateral outrepassé flaking at Locality 36 is very low (n=5); it seems unlikely that its appearance in the assemblage is intentional. Only one biface exhibiting lateral outrepassé flaking showed use of one of the two thinning techniques mentioned above (thinning from a square edge). None was heat-treated.

Presence/absence of a recently described biface reduction technique, "the unifacial biface technique" (Skinner 1991), reported at several sites in Mono County, California, was examined in this analysis. It is said to be a distinctive biface reduction technique common in the Central Valley of California and the Sierras, extending to Northern California and Idaho (Skinner 1991, Skinner and Ainsworth 1991). The technique is said to consist of the use of side-struck, biconvex flakes requiring neither edging stage nor advanced dorsal reduction (early/middle Stage 4) prior to ventral thinning. This means that both primary and secondary thinning are performed on the dorsal face before thinning is initiated on the ventral face. In contrast, the Coso technique uses flakes detached from extensively reduced bifaces as biface blanks, resulting in flakes with worked dorsal surfaces (ca. mid Stage 3) and unworked ventral surfaces (Elston and Zeier 1984). A unifacial biface technique has been said to influence relative dimensions of bifaces and proportions of debitage types, and thus to invalidate most staging schemes (Skinner 1991:247).

Extensive use of a unifacial biface technique should be recognized easily in quarry contexts, where bifaces frequently are broken in various stages of reduction. To investigate this at Locality 36, both as a distinctive cultural trait and to judge its effect on our staging scheme, the extent of reduction on each face of the Locality 36 bifaces was recorded separately (Table 23); other variables involved in Callahan's staging scheme (cross-section and width/thickness ratio) cannot be addressed when only one face is examined.

Table 23. Unifacial Biface Technology at Locality 36.

	Dorsal Face						
	Stage 1	Early 2	Late 2	Early 3	Late 3	Early 4	Late 4
Ventral Face							
Stage 1	3	2	2	4	1		
Early 2	2	30	10	3			
Late 2			60	17	3		
Early 3	1	2	10	228	8		
Late 3				1	56		
Early 4						3	
Late 4							1

n=475 of a total of 635 (this includes 103 bifaces on which the dorsal and ventral faces are distinguishable and 372 on which both faces are reduced equally.

Proportions of bifaces made using the unifacial biface technique are not presented for the Mono County sites, precluding comparison of their frequencies to other assemblages. Nevertheless, the large numbers of early stage bifaces at Locality 36 provide a good test of the presence of the technique. There are very few bifaces conforming to the pattern described for unifacial biface technique (Table 23). Only four specimens in the Locality 36 biface assemblage were reduced extensively on the dorsal surface before primary thinning on the ventral surface, while 24 exhibit primary thinning on the dorsal face before primary thinning was initiated on the ventral face. Thirteen examples exhibited primary thinning on the ventral face before primary thinning was started on the dorsal face. Most bifaces in the assemblage were reduced equally on each face. It seems unlikely that the unifacial biface technique is significant as a cultural or chronological marker at Tosawihi; biconvex flake blanks occasionally were used for the production of bifaces, but they were edged in the same way as others in the assemblage (Moore 1992:Figure 37). Although a small number of bifaces in many biface industries contain examples on which dorsal reduction preceded ventral reduction, unless large proportions of the bifaces in the assemblage exhibit such patterning, a specialized reduction technique is unsupported. The contextual associations of square edge and end-thinning, the two specialized reduction techniques appearing in the Locality 36 assemblage, are examined in Chapter 8.

Thermal Alteration

Thermal alteration affects the appearance and flaking quality of opalite, making it more vitreous, lustrous, and brittle, as well facilitating controlled flaking. Heat-treatment commonly was used prehistorically in much of North America, both in biface and projectile point manufacture. The process usually involves building a fire over a pit in which silicious raw material or unfinished tools are buried, and it can be performed at various points in the manufacturing process. The stage at which bifaces are heat-treated often can be determined by comparing lustrous and non-lustrous negative flake scars. When a partially finished biface is heat-treated, the existing negative flake scars will retain the dull surface of the non-heat-treated piece, but if worked subsequently, any new removals will have a glassy, lustrous appearance. Thus, if a piece is worked only minimally after heat-treatment and then discarded, the stage can be determined; if it is worked extensively however, all traces of the dull surface will be removed and only lustrous scars will remain, rendering stage of heat-treatment impossible to determine.

At Tosawihi, heat-treatment was important in the biface manufacturing process (Bloomer, Ataman, and Ingbar 1992). In previously investigated assemblages, 40% of the bifaces were heat-treated; of these, most were heat-treated roughly midway though the reduction sequence. In contrast, only 6.8% of the bifaces from Locality 36 are heat-treated (Table 24). Although this proportion is much lower than those among earlier assemblages, it is comparable to proportions reported for non-Tosawihi quarry sites. These additional data confirm our impression that only rarely was heat-treatment carried out at quarries where no adjacent residential sites occurred (cf. Elston 1992b).

Table 24. Heat-Treatment in the Biface Reduction Sequence.

	n	%
Heat-treated as a Stage 2 Biface	6	0.9
Heat-treated as a Stage 3 Biface	13	2.0
Heat-treated during Reduction but Stage Indeterminate	3	0.5
Heat-treated but Stage Indeterminate	11	1.7
Possibly Heat-treated	9	1.4
Thermally Altered Post-deposition	1	0.2
Not Heat-treated	592	93.2
Total	**635**	**100.0**

Only 33 bifaces recovered from Locality 36 were heat-treated. An additional 9 may have been heat-treated. The proportion of heat-treated bifaces within each manufacturing stage increases through the reduction sequence (Table 25). There is minimal heat-treatment in the early stages of reduction, but 12% of the middle Stage 3 bifaces and 20% of the late Stage 3 bifaces were heat-treated.

Table 25. Heat-treatment of Bifaces by Stage.

Bifaces	Heat-treated	Possibly Heat-treated	Not Heat-treated	Total	% Heat-treated
Stage 1	0	0	3	3	**0**
Early Stage 2	0	0	31	31	**1.0**
Late Stage 2	1	0	98	99	**1.0**
Early Stage 3	8	3	332	43	**2.3**
Mid Stage 3	13	1	93	107	**12.1**
Late Stage 3	5	2	18	25	**20.0**
Stage 4	2	2	2	6	**33.3**
Stage 5	2	0	0	2	**100.0**
Indeter. Stage	2	1	16	19	**10.5**
Total	**33**	**9**	**593**	**635**	**100.0**

Manufacturing Failure

Bifaces fail for a variety of reasons: raw material flaws, knapping mistakes, unworkable edges or unacceptable proportions, thermal failure during heat-treatment. Reasons for discard are linked to these failures; some are functional *(i.e.,* they no longer can be made into the intended form), some to cultural preference regarding size, proportion, or shape.

In general, bifaces tend to break more frequently during later stages of reduction. Fatal breaks are less likely to occur during Stage 2 because 1) pieces are larger then and it is easier for the knapper to recover from mistakes, and 2) when only edges are being prepared, less force is necessary for flake detachment, and mistakes are less likely to be uncorrectable. The risk of breakage increases when primary thinning is initiated (Stage 3) and is even greater during secondary thinning (Stage 4), when the biface is thinner and more susceptible to misplaced or misangled hammer blows.

Of the 50% of bifaces which broke during manufacture, approximately half broke due to flaws in the raw material (Table 26). The other half broke probably owing to knapper error. Most broke due to misplaced blows resulting in hinge or outrepassé terminations, edge collapse (which may reduce the width of the biface significantly), or from perverse or bending breaks resulting in fragmentation.

Many more bifaces were discarded unbroken at Locality 36 than at other Tosawihi sites studied so far. Unbroken bifaces probably were discarded due to their unacceptable proportions. When width/thickness ratios of complete pieces by stage are compared between Locality 36 and the earlier assemblage, those from Locality 36 are consistently lower, indicating that thinning of these pieces was less successful. Stacked fractures, low width/thickness ratios, and edge collapses all can lead to discard. Many of these problems are a function of knapper error.

Table 26. Biface Breakage Type.

Stage	Unbroken n	Unbroken %	Material Flaw or Fracture Plane n	Material Flaw or Fracture Plane %	Hinge/Outrep. n	Hinge/Outrep. %	Edge Collapse n	Edge Collapse %	Perverse/Bend. n	Perverse/Bend. %	Thermal n	Thermal %	Other/Indet. n	Other/Indet. %	Total n	Total %
Stage 1	2	0.67	0	0.00	0	0.00	0	0.00	1	1.02	0	0.00	0	0.00	3	0.47
Early 2	21	7.07	5	3.16	0	0.00	0	0.00	4	4.08	0	0.00	1	4.76	31	4.88
Late 2	56	18.85	25	15.82	8	22.22	1	5.88	5	5.10	0	0.00	4	19.05	99	15.59
Early 3	171	57.57	81	51.27	22	61.11	5	29.41	53	54.08	1	12.50	10	47.62	343	54.02
Mid 3	43	14.48	33	20.89	3	8.33	3	17.65	16	16.33	4	50.00	2	9.52	107	16.85
Late 3	2	0.67	7	4.43	2	5.55	1	5.88	9	9.18	2	25.00	1	4.76	25	3.94
Stage 4	1	0.34	0	0.00	0	0.00	0	0.00	4	4.08	1	12.50	0	0.00	6	0.94
Stage 5	0	0.00	2	1.27	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.31
Indeterm.	1	0.34	5	3.16	1	0.28	7	41.12	2	2.04	0	0.00	3	14.29	19	2.99
Total	297	46.77	158	24.88	36	5.67	17	2.68	98	15.40	8	1.26	21	3.31	635	100.00

Discussion

Biface Production Techniques

While biface reduction technology may have changed through time, in every period the decision to use one blank type or another probably considered toolstone utility maximization strategies (toolstone being difficult as well as expensive to extract [*cf.* Chapter 9]). When small blocks of toolstone were extracted it probably was more advantageous to reduce them directly into bifaces without an intervening flake blank stage. On the other hand, when a large block of good quality material was extracted, it would have been more advantageous to produce a number of flakes from it to use as biface blanks. It is likely that at least some flake blanks were selected from early stage block reduction debitage, which often includes suitable small biface flake blanks (this is another method of maximizing the utility of extracted toolstone). However, the nature of biface blanks cannot be addressed solely with reference to bifaces. Core, modified chunk, and debitage studies, as well as flake blank and block-based biface contexts, all provide data to address the issue, and are considered in later discussions.

Specialized reduction techniques also may have been developed to maximize utility in response to the nature of the toolstone. While unifacial thinning on square edges (the most common specialized technique noted in the assemblage) may be used occasionally in flake-based biface reduction, it clearly is most useful for thinning blanks with several squared edges such as are found on block blanks. Whether this technique was part of the technology employed in the earliest visits to Locality 36 or was adopted later is discussed in later chapters.

Export Stage and Form

In our previous work at Tosawihi we concluded that most prehistoric occupation of the area was of short duration and was related primarily to the procurement and processing of toolstone intended for use elsewhere (Elston 1992b). Thus the bifaces produced at Tosawihi were exported out of the area of production.

One of the questions we are interested in addressing with the present analysis asks the form and stage of bifaces leaving Locality 36. We assume that many of the bifaces recovered at Tosawihi sites peripheral to the quarry proper (26Ek3032) were reduced initially near the areas where the toolstone was extracted. This pattern fits models of return maximization and transport cost minimization previously proposed for predicting artifact distributions at Tosawihi (Elston 1992c); *i.e.*, it is not cost-effective to transport raw material mass that later will be discarded as waste. Empirical evidence from sites in the Western Periphery and the Northern Corridor (Leach, Dugas, and Elston 1992; Schmitt and Dugas 1992), the areas farthest from the quarry proper, supports this contention. Although there is evidence for a limited amount of reduction of previously unworked flake blanks, most biface reduction undertaken in these areas was of already partially reduced bifaces (Bloomer and Ingbar 1992). Thus, it is likely that many bifaces produced at Locality 36 were transported to other sites in the Tosawihi vicinity and further reduced before leaving the area, especially if we find that bifaces exported from Locality 36 were earlier in stage than those from the quarry peripheries. Other replication and archaeological studies of breakage (Amick 1985; Sassaman, Hanson, and Charles 1988) have noted that successive stages of reduction, heat-treatment, and soft hammer use tend to increase breakage rates. If the incidence of broken pieces serves as proxy for breakage rates, various scenarios of export can be modeled.

We examine the question of export stage with several classes of data. We use incidence of breakage in each stage of the reduction sequence in the archaeological assemblage and observation of biface breakage in experimental replications to set up expectations about breakage. Then, from the proportion of the total represented by each stage in the archaeological assemblage (using only broken examples), breakage rates and export stages are modeled.

The proportion of broken bifaces in each stage of the reduction sequence at Locality 36 is shown in Table 27. The proportion of broken bifaces steadily increases from early Stage 2 to mid Stage 3; the greatest increase occurs between middle Stage 3 and late Stage 3, after which, the proportion of broken pieces decreases. The number of specimens in Stages 1, 4, and 5 is very low, but the pattern of slowly increasing breakage through the first three stages, with the greatest increase between mid and late 3, is clear.

Table 27. Proportions of Broken Bifaces by Reduction Stage.

	Complete	Broken	Total	% Broken
Stage 1	2	1	3	33.3
Early Stage 2	21	10	31	32.2
Late Stage 2	56	43	99	43.4
Early Stage 3	174	169	343	49.3
Mid Stage 3	46	61	107	57.0
Late Stage 3	1	24	25	96.0
Stage 4	1	5	6	83.3
Stage 5	1	1	2	50.0
Indeterminate	1	18	19	94.7
Total	**303**	**332**	**635**	**47.5**

A simple mathematical simulation model of biface production can be made using insights gleaned from experimental flintknapping and the available archaeological data. We start with a pool of 100 Stage 1 bifaces. The overall success rate (*i.e.*, proportion of bifaces successfully reduced for transport) is fixed at 70% (a figure derived from experimental success rates). Thus, sometime prior to transport, 30 bifaces must break. Their distribution across stages must match the observed archaeological distribution of biface stages. Two terms are allowed to vary in the simulation: breakage rate from each stage to the next and number of bifaces leaving the assemblage at each stage. Breakage rates are determined, in part by number of bifaces transported, since these are removed from the pool of bifaces available to break. As well, based upon experimental research, breakage rate must increase initially and then decline. "Transporting" differing numbers of bifaces at each stage following Stage 2 (since there is no archaeological evidence for transport of Stage 1 or Stage 2 bifaces) causes the breakage rates to change. With the entire model in a spreadsheet, one simply changes the number of bifaces "transported" at each stage and examines the resulting breakage rates to see if they (1) fit the pattern of the archaeologically observed breakage rates and (2) also fit the pattern of initial increase followed by decrease in later stages of reduction.

Different export scenarios can be explored easily using this simulation. If 70 out of 100 initial bifaces are successful (*i.e.*, transported off-site), we can build a model in which half of these 70 bifaces (*i.e.*, 35% of the initial 100 bifaces) are transported in a given stage. The other 35 successful bifaces (*i.e.*, 35% of the initial assemblage) can be modelled as having been removed in the very next stage, or successive reduction stages, following the first transport pulse. Using this technique while examining bifaces recovered elsewhere at Tosawihi, we concluded that 50% of the bifaces leaving the quarries were middle Stage 3, 50% were late Stage 3 or later, and most were heat-treated (Ataman and Bloomer 1992). Examination of several museum collections from sites in the greater Tosawihi region supported the conclusion that few, if any, Stage 1 or Stage 2 bifaces left Tosawihi for destinations outside the production area, most were mid Stage 3 or later, and almost all were heat-treated (Ataman and Bloomer 1992).

At Locality 36, as might be expected, exported bifaces left in an earlier, non-heat-treated state. If we assume, as above, that breakage increases steadily through the reduction sequence to early Stage 3, then increases more steeply between middle and late Stage 3, and that probably only a small number of Stage 1 and Stage 2 bifaces left the quarry, we conclude that early Stage 3 bifaces were the primary (approximately 75%) export. The remaining exports (25%) probably left Tosawihi in middle and late Stage 3 form.

The question of intended form and proportion is even more difficult. No biface caches, where successful products were stored, were recovered at Locality 36, as they have been on the quarry, and we have few examples of finished tools. Most artifacts in our collection represent rejected and discarded items. Complete artifacts suggest unacceptable forms, and pieces broken later in reduction suggest intended forms. But this is negative evidence that cannot identify intended products unequivocally. It seems clear, however, that discarded bifaces in our assemblages are there because they could not be thinned. This bolsters our impression, which must remain unsupported until work farther afield at Tosawihi can be undertaken, that these thinned bifaces were unsuitable as flake cores (except perhaps incidentally), and that the successful products served primarily as knife preforms (Ataman and Bloomer 1990, 1992).

Comparison to Other Quarry Assemblages

Comparison of the biface assemblages from Locality 36 and other Tosawihi quarry sites is informative, providing a measure of the uniqueness of Locality 36 and perhaps indicating the most important factors shaping strategies of extraction and processing in particular circumstances. We compare biface assemblages from two other Tosawihi quarry sites with the Locality 36 material. These two sites, which have almost equal biface assemblage sizes, are Locality 26 of 26Ek3032, a quarry pit site along the lower reaches of Little Antelope Creek (Leach and Botkin 1992), and 26Ek3208, an outcrop quarry in the Western Periphery (Leach, Dugas, and Elston 1992). Locality 26 is a small site where moderately good raw material occurs in relatively shallow deposits, while 26Ek3208 exhibited thick deposits of high quality material that was exploited extensively. In terms of biface stages and proportions of unbroken bifaces, 26Ek3208 and Locality 36 are somewhat similar, but no clear patterns emerge from comparison of other attributes (Table 28).

Table 28. Comparison of Quarry Biface Assemblages

	Locality 26	26Ek3208	Locality 36
Total n	59	55	635
Reduction Stage (%)			
Stage 1	0.0	0.0	0.5
Early 2	23.6	3.3	4.9
Late 2	14.5	13.5	15.6
Early 3	41.8	62.7	54.0
Mid 3	20.0	16.9	16.8
Late 3	0.0	3.4	3.9
Stage 4	0.0	0.0	0.9
Stage 5	0.0	0.0	0.3
Blank type (%)			
Flake	15.2	21.8	13.7
Block	10.2	10.9	6.9
Complete Bifaces %	28.8	47.3	46.8
Heat-treatment %	3.4	3.6	5.2
Sq. Edge Thinning %	11.9	23.6	15.0
End Thinning %	10.2	20.0	6.0
Mean Weight (complete)	198.4	174.3	318.8

Toolstone quality at Locality 26 is lower than at Locality 36 and 26Ek3208 (Dugas, personal communication 1991). Flawed toolstone could result in a high breakage rate contributing more than thinning attempt failure to biface discard. The greater use of both flake and block reduction at 26Ek3208 is more difficult to explain. On the one hand, high toolstone quality could lead to greater reliance on a flake-based approach; on the other, a high frequency of block reduction leads to higher use of the square edge thinning technique. The stages of reduction at 26Ek3208 and Locality 36 are quite similar, and may be related to both the quality and size of material extracted. The frequency of heat-treatment at all three sites is low, indicating that only rarely was the technique performed at quarry sites. Thus, the nature of biface assemblages at quarry sites (that is, proportions of reduction stages present, blank type, thinning techniques, incidence of breakage, and amount and patterning of heat-treatment) is highly idiosyncratic. Differences among these assemblages probably owe primarily to the nature of the raw material in each deposit rather than to other factors.

The Flake Tool Assemblage

Flake tools are defined here by the presence of retouch that appears deliberate rather than a consequence of use or of post-depositional processes. This is a conservative approach to flake tool categorization adopted because, in quarry contexts, it is nearly impossible to distinguish use-induced retouch from post-depositional damage. Our conservatism probably has resulted in an at least slight under-representation of lightly used tools. Examination of unretouched debitage from previous work at Tosawihi indicated that unretouched flakes were used occasionally for tasks requiring a sharp edge with a straight profile (*i.e.*, cutting), but that many tasks required tools with shaped and strengthened edges (Ataman 1992). It is likely that unretouched debitage was used to a limited extent at Locality 36.

The morphological typology devised previously for Tosawihi was used to classify flake tools at Locality 36; technological characteristics were noted, and functional analysis was conducted on each piece. Observations of twenty-four flake tools were recorded.

Raw Material

All flake tools are of opalite. Opalite in the Tosawihi area is highly variable in color and texture and some sources are very distinctive. At Tosawihi, color variation in any artifact assemblage provides a rough indication of opalite source diversity, but, as noted earlier, most tool material at Locality 36 is white, grey, or beige, and we can assume that the vast majority of bifaces collected there are rejected manufacturing stage bifaces derived from that source. Over 97% percent of the biface assemblage is grey, white, or beige opalite while 83% of the flake tool assemblage is of the same color range.

Type

Flake tools were classified on the basis of a morphological typology previously established for Tosawihi assemblages (Ataman 1992); the results are presented in Table 29.

Table 29. Flake Tool Types at Locality 36.

Type	n	%
Side Scraper	1	4
End Scraper	1	4
Misc. Scraper	4	17
Subtotal	**6**	**25**
Bifacial Tool	2	8
Pointed Tool	1	4
Notch/Denticulate	4	17
Subtotal	**7**	**29**
Flake w/cont. retouch-single edge	3	13
Flake w/cont. retouch-multiple edges	2	8
Flake w/localized retouch	1	4
Subtotal	**6**	**25**
Pressure flaked fragment	3	13
Other fragment	2	8
Subtotal	**5**	**21**
TOTAL	**24**	**100**

Size

Seven of the 24 flake tools are complete: average length of complete tools is 79.8 mm, average weight 65.6 g. Size varies. Scrapers and notches tend to be large, and fragments of tools usually are small (Figures 41, 42).

Technology

A paucity of cores in the assemblage indicates that flakes used for flake tool blanks probably were by-products of other reduction activities such as biface manufacture. However, blank types on which Locality 36 flake tools were made often are not distinguishable, and only a few can be identified definitely as biface thinning flakes. Blank shapes are quite variable, as are the shapes of retouched edges. Sixty-six percent were retouched on a single edge and 33% on more than one edge. The retouch on 50% of the pieces is direct (dorsal retouch), 25% inverse (ventral retouch), and 25% bifacial. The edge angles of the retouched edges also are variable; 50% are medium, 25% acute, and 25% obtuse angles.

A small number of tools (n=5) exhibits pressure flaking, which at Tosawihi usually is associated with heat-treated tools. Heat-treatment generally is not found on non-pressure flaked specimens, suggesting that heat-treated debitage rarely was used for flake tool production at Locality 36 and that heat-treated flake tools probably were less useful for the tasks undertaken there. Heat-treated opalite is brittle and does not hold a sharp edge, and thus is unsuitable for heavy-duty tasks.

Function

All flake tools were examined for use-wear traces using a binocular metallurgical microscope at magnifications of 50x, 100x and 200x, following procedures outlined for previous Tosawihi work (Ataman 1992). No attempt was made to identify precise function; we looked instead at motion of use, hardness of worked material, and intensity of use of each tool.

Eleven of the 24 tools exhibit clear evidence of use. Two pieces exhibit light use intensity, four medium intensity and five heavy intensity (Table 30).

Table 30. Motion of Use and Hardness of Worked Materials.

	Hardness				
Motion	Soft/Med.	Med.	Med./Hard	Indet.	Total
Scraping	2	2	4	0	8
Boring or Drilling	0	0	1	0	1
Chopping	0	0	1	0	1
Indeterminate	0	1	0	13	14
Total	**2**	**3**	**6**	**13**	**24**

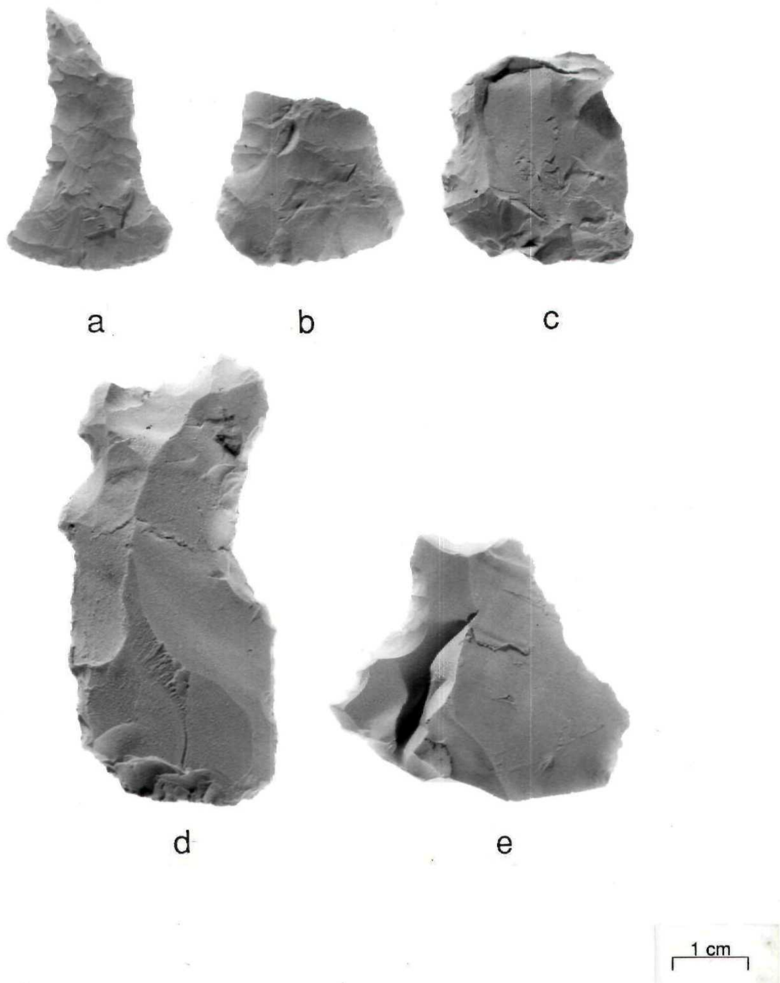


Figure 41. Selected small flake tools.

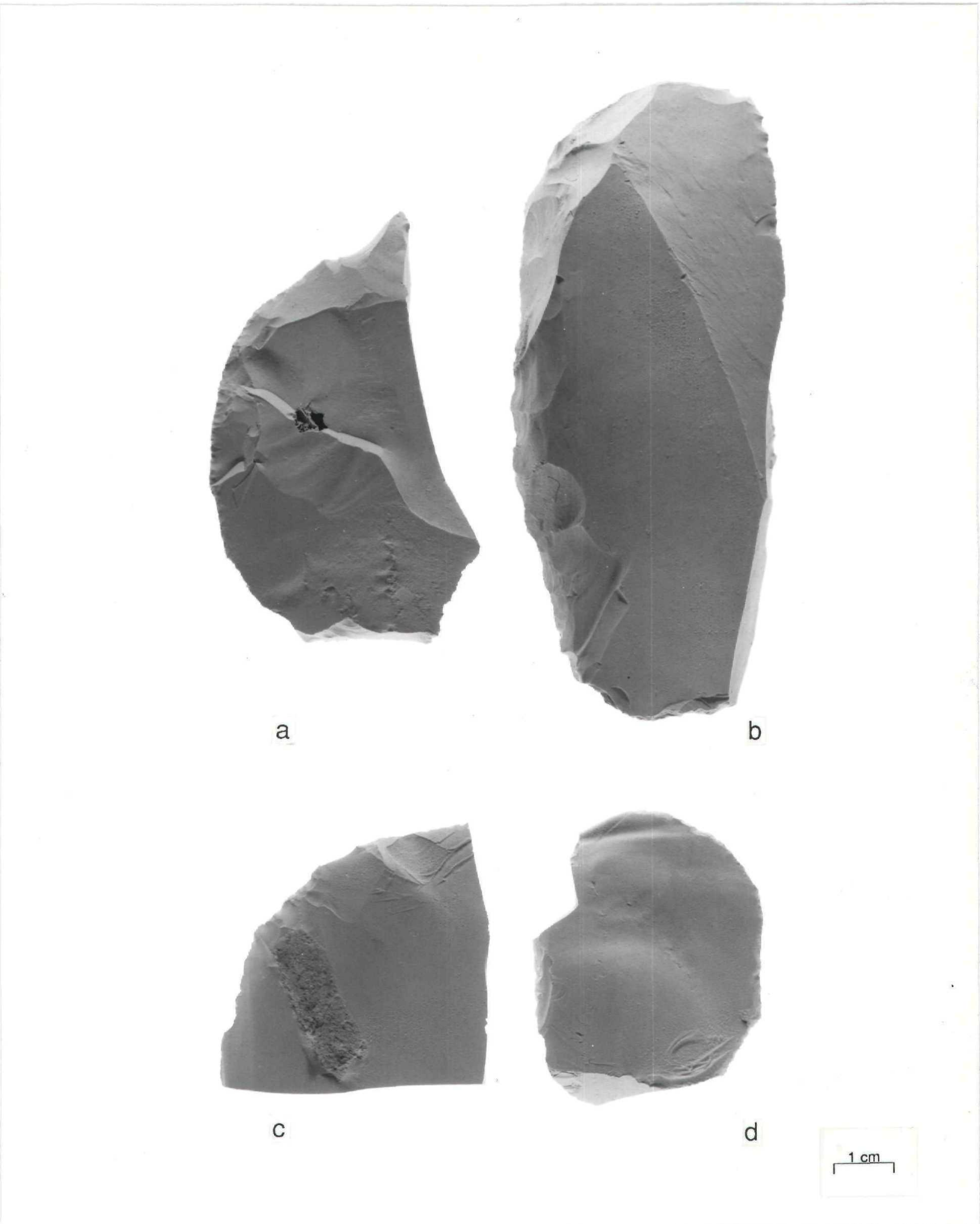


Figure 42. Selected large flake tools.

Flake tools at Locality 36 suggest primarily expedient use for a variety tasks. The flake tools appear to be made on local material, and they are extremely variable in form, blank type, blank shape, and edge angle. Few are made on biface thinning flakes, perhaps reflecting the early nature of reduction at this site. Many would be useful in manufacturing and maintaining quarrying tools such as those observed archaeologically and reconstructed through experimental quarrying. Most of the utilized stone tools exhibit moderate or heavy use intensity.

Projectile Points and Preforms

Four projectile points were recovered from Locality 36. Typological criteria and temporal constraints employed in this analysis follow those outlined by Thomas (1981). This system assigns projectile points to temporal series on the basis of morphological observations including length, width, thickness, weight, basal width, and notch angles: the "series is the time-bearing unit and the type is merely a morphological modifier" (Thomas 1982:160). Chronological and morphological attributes for the Great Basin Stemmed Series, not addressed by Thomas (1981), follow Layton (1979), Clewlow (1968), and Frison (1978).

The points consist of two Great Basin Stemmed points, one Gatecliff Split-stem point, and one Desert Side-Notched (DSN) point (Figure 43). One of the stemmed points was made of a light colored chert while the remaining three points were made of obsidian. Whether the chert specimen was Tosawihi opalite could not be determined, having been burned after deposition. Under an ultraviolet light the piece reflects orange light characteristic of burning.

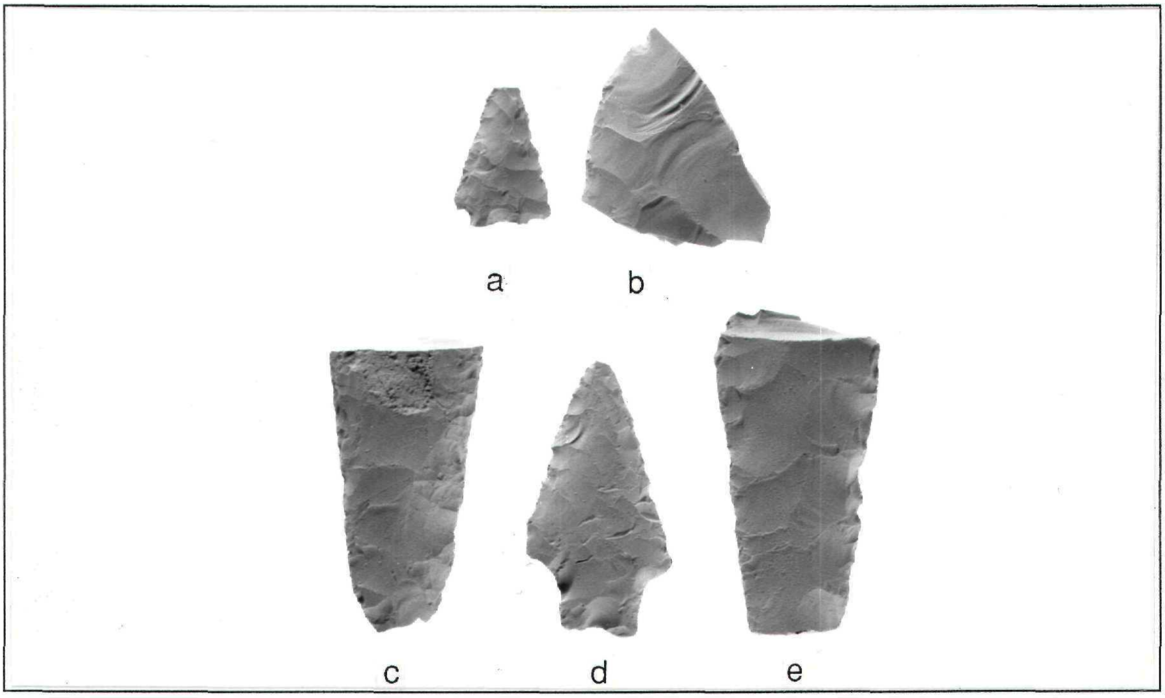


Figure 43. Projectile points and preforms. a. obsidian Desert Side-notched; b. opalite preform; c. chert Great Basin Stemmed; d. obsidian Gatecliff Split-stem; e. obsidian Great Basin stemmed.

Three of the points (DSN, obsidian stemmed, and Gatecliff Split-stem) exhibit traces of use. None exhibits clear evidence of reworking.

The two Great Basin stemmed points are basal fragments with bending breaks, the DSN was broken both at tip and through the notches; the Gatecliff point was unbroken. None can be seen to have been made directly on a flake blank and only the stemmed points exhibit percussion flaking (and no pressure-flaking). Both stemmed points have ground edges. Four points were recovered from surface contexts and do not provide clear evidence for contemporary use of the quarries.

The three obsidian points were examined for sourcing and hydration information (cf. Appendix A). Both the sourcing and hydration data are compatible with those from the previous Tosawihi investigations (Elston and Drews 1992). The stemmed point derives from the Brown's Bench source, while the obsidian of the two later points is from Paradise Valley. The stemmed point has a mean hydration rind thickness of 10.3 microns, the Gatecliff, 2.5, and the DSN of 1.5.

Most radiocarbon dates from Locality 36 reflect dates later than those suggested by obsidian point hydration, but there are several dates from the bottom of quarry pits that cluster around 4000 B.P. Considering the distribution of stemmed points in the Tosawihi area as a whole, the stemmed points may have been discarded during visits to Tosawihi unrelated to opalite extraction and processing.

One preform fragment was recovered (Figure 43b). It is made of white opalite that was heat-treated as a flake, and exhibits edge abrasion and pressure flaking along its only intact edge.

Cores

A core is defined here as a block of raw material from which pieces intended for use or modification have been detached, a by-product of reduction. In a biface industry, cores may resemble failed bifaces. Similarly, a single piece may function as both a core and biface and, as a result, the two often are difficult to distinguish. For this reason we have identified pieces as cores only when they do not exhibit biface morphology. The core assemblage from Locality 36 is very small, numbering 16 artifacts.

The objective of core analysis is to determine whether a flake/core technology was used to produce flake blanks for the production of bifaces and other tools, or for export as flakes. Cores may be reduced to bifaces, or they may be discarded when they fail or become exhausted. Only in the latter case can core reduction be recognized easily. Another objective of core analysis is to determine patterns in core reduction technology.

All the cores are made of grey or white opalite and are quite variable in size. Of ten complete specimens, the average weight is 567.9 g (s.d.=327.3, CV=0.58). Overall core shape is primarily blocky or irregular, although two are conical and two are globular (Figures 44, 45). The number of platforms on each core varies but most bear two or three platforms. Most worked faces are unidirectional, bearing a single platform. In a few cases, platform faces exhibit opposed or crossed platforms. On six examples, all worked faces have unidirectional removals, but four have both single and multiple faced platforms, either opposed or crossed. In addition, four examples have multiple platforms with randomly oriented worked faces.

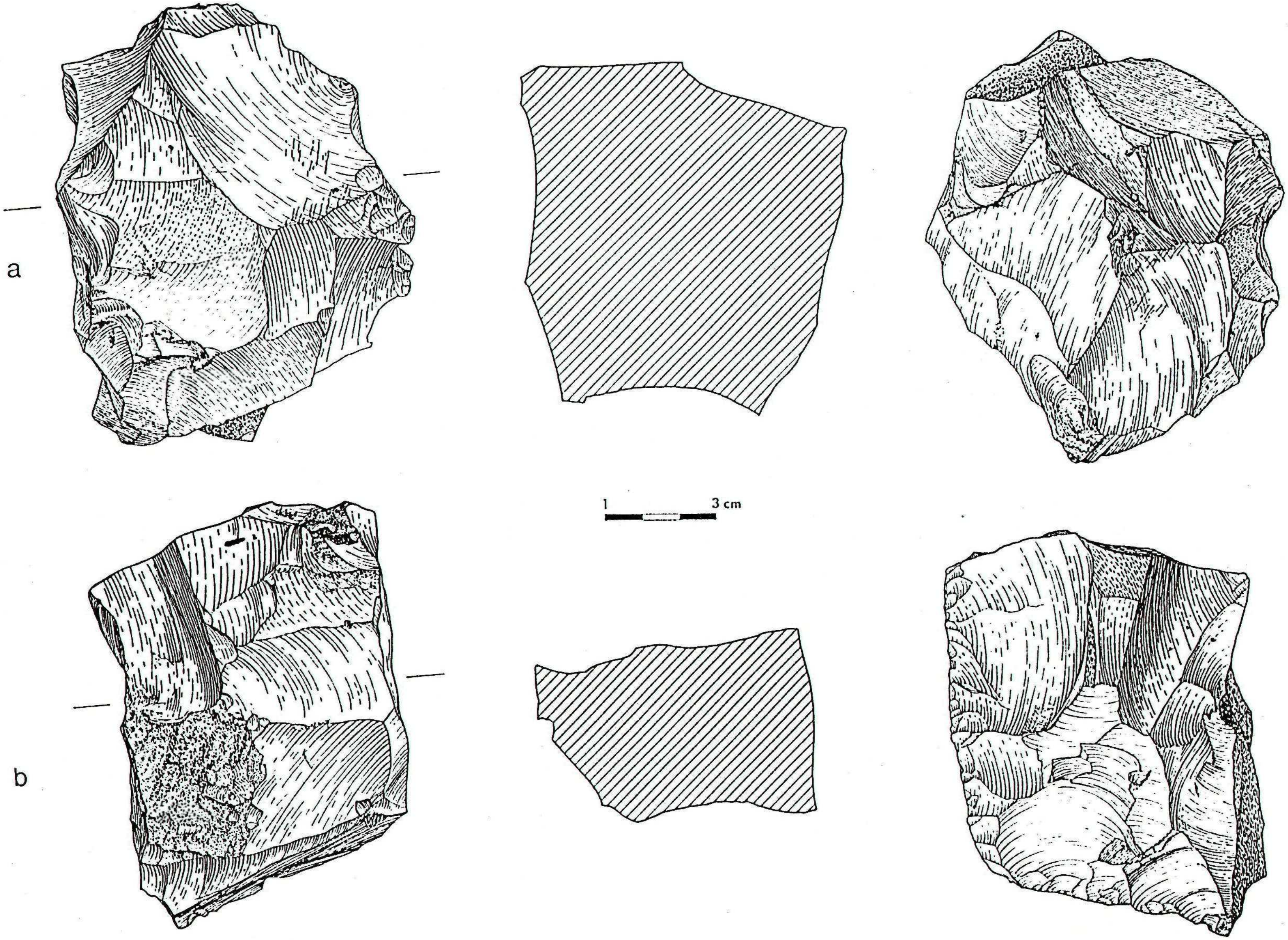


Figure 44. Selected cores: a. globular core; b. blocky core.

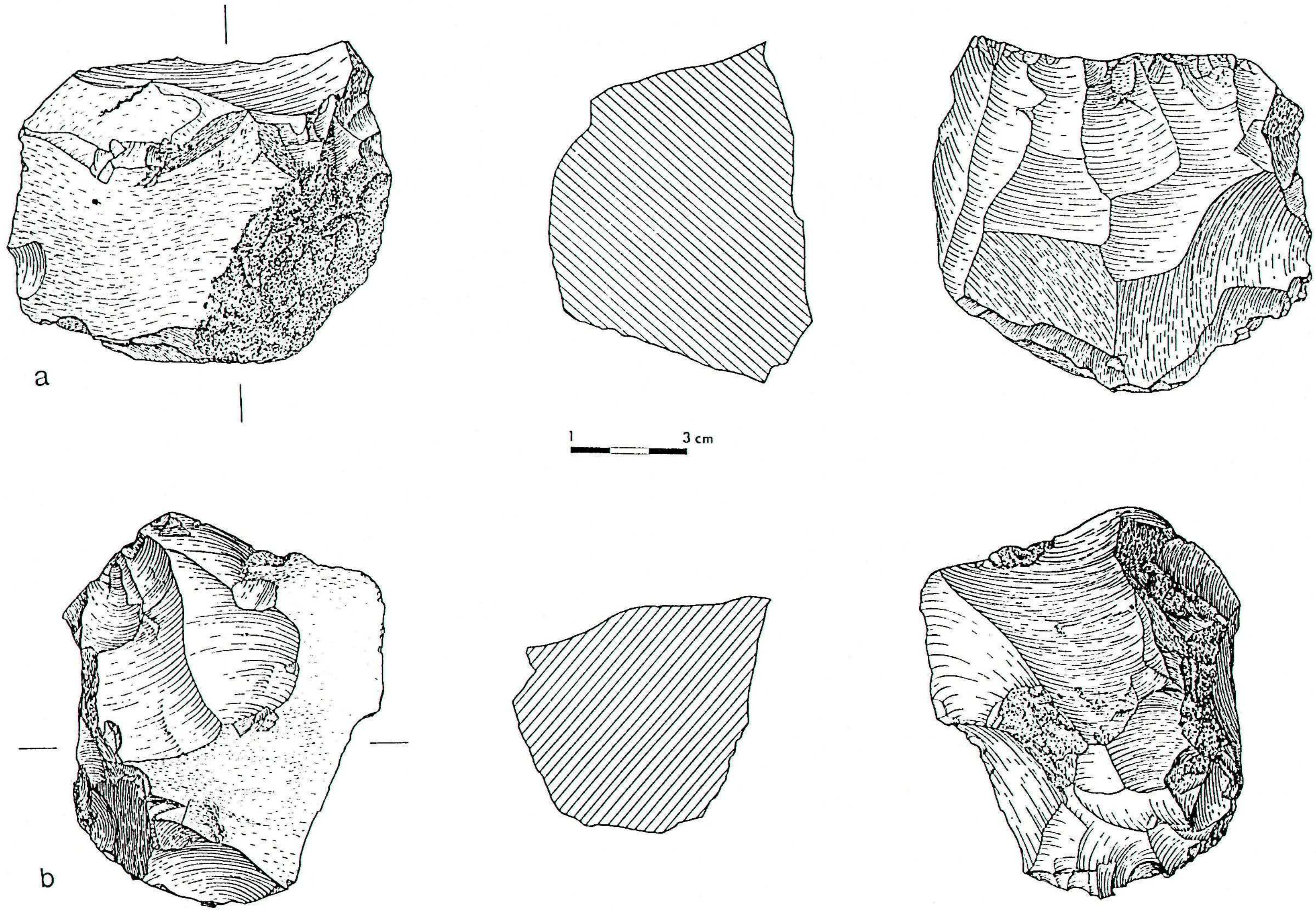


Figure 45. Selected cores: a. single platform core; b. conical core.

For many specimens, we could not determine the reason for their failure and discard. However, six appear to have been exhausted, (*i.e.*, no suitable platform remained) and three broke, two as a result of material flaws.

The number of cores is so small, and their sizes, forms, and platform orientations so variable, that it is difficult to evaluate their place in the lithic industry of Locality 36. On the other hand, at least 13% of all recovered bifaces were made on flakes and the recovered core assemblage does not begin to account for that number. Thus, much of the core reduction technology employed at Locality 36 is invisible. Whether or not flake production for export was practiced seems doubtful but cannot be discounted entirely. The lack of patterning in the identified core assemblage, however suggests that flakes could not have been a primary export product.

Modified Chunks

Modified chunks are angular pieces of debitage, often as large as cores or bifaces, that have been modified deliberately, but that do not exhibit the morphology or patterned flake removals of *either* core or biface reduction. They may represent assayed pieces, expedient cores, failed bifaces, or unique products of quarry-related reduction.

Weights, presence or absence of cobble cortex, and number of deliberately produced flake scars present on each piece were recorded. One hundred twenty-seven modified chunks were collected in the course of work at Locality 36, weighing in total a little more than 62 kg; mean weight is 490.2 g. The standard deviation for weight is 454.6 g and the coefficient of variation 0.927, indicating that these artifacts are highly variable in size. Weight does not seem to be associated with number of flake scars on a modified chunk, so it seems unlikely that chunks represent exhausted cores (in which case, weight might be expected to decrease with increase in number of flake scars).

Nor is there any apparent relationship between number of flake scar and presence/ absence of cortex. The number of pieces with cortex (n=14) suggests that some portion may represent assayed cobbles or large hammerstone fragments (colluvial opalite cobbles were common choices for large hammerstones). The number of flake scars present on modified chunks ranges from one to nine, most having from one to five. The greater number of scars on some pieces suggests they actually may have served as cores but were not classified as such due to lack of patterning and relatively small size of flake scars.

From this brief analysis we conclude that modified chunks recovered from Locality 36 represent discarded fragments of a variety of implements related to quarrying or early stages of toolstone reduction. The highly variable size among chunks suggests that extracted block size also may have been highly variable. The locations of these pieces indicate areas where the very earliest stages of reduction were conducted; thus, we might expect to find them concentrated in and around quarry pits. This is, indeed, the case. Of the 127 modified chunks in the assemblage, 66% were recovered from quarry pits, 18% from reduction features, 14% from non-feature contexts, and 2% from hearth features (cf. Chapter 10).

Summary

With the exception of most projectile points, the flaked stone artifacts reviewed in this chapter were produced from Locality 36 raw material. They differ however, in manufacture and function. Bifaces were the focus of production at Locality 36: modified chunks and cores were by-products of that industry. Along with bifaces, they constitute the majority of the flaked stone artifact assemblage. Flake tools, rare as they are, seem to have been produced expediently, then used, and finally discarded in aid of quarrying activities.

Modelling biface breakage and transport rates showed that bifaces commonly were exported from Locality 36 as early Stage 3, non-heat-treated, unfinished tools. On the basis of indirect evidence, we think bifaces were removed from the quarry to nearby campsites for further reduction prior to export from Tosawihi.

Bifaces maintained a standard form throughout the 4000 years of quarry use, and production techniques show slight evidence of change through time. Variation in biface production techniques evident at Locality 36 seems due to the characteristics of particular deposits exploited.

Chapter 6

HAMMERSTONES AND ADDITIONAL ARTIFACTS

Dave N. Schmitt and Caitlin M. Carroll

Archaeological investigations at Locality 36 returned numerous stone and bone implements employed in toolstone extraction and fabrication and ground stone tools used to process subsistence resources. The following discussion segregates assemblage components into four analytic categories: hammerstones, metates, bone artifacts, and other artifacts. Functional ascriptions are based on observations of overall morphology, provenience, and comparison with regional archaeological assemblages.

Hammerstones

Excavations and surface collections yielded one of the largest collection of hammerstones recovered from a Great Basin site. Represented by a wide range of shapes, sizes, and material types, 145 hammerstones were collected from various contexts, including extra-feature surface finds, quarry pits, and isolated reduction features (Table 31).

Table 31. Hammerstone Frequencies by Material at Locality 36.

Type of Investigation	MATERIAL Basalt	Quartzite	Rhyolite	Opalite	Other	Total
Non-feature						
Surface	4	3	9	1	-	17
Subsurface	-	2	-	1	-	3
Misc. Trench Backdirt	7	7	5	11	9	39
Feature						
Misc. Feature Inventory-Surface	6	6	8	5	4	29
Excavated/Profiled Contexts						
Quarry Pits*						
Feature 13	-	-	2	-	-	2
Feature 22	-	3	-	2	-	5
Feature 30	-	1	-	-	-	1
Feature 31	-	1	-	-	-	1
Feature 32	-	-	-	2	1	3
Feature 42	1	2	2	1	1	7
Feature 42/44	2	2	-	-	-	4
Feature 49	2	2	1	-	2	7
Feature 72	2	3	-	-	-	5
Feature 102	6	4	5	1	1	17
Reduction Features						
Feature 6	-	1	-	-	-	1
Feature 63	-	1	-	-	-	1
Feature 84	-	1	-	-	-	1
Feature 86	1	-	-	-	-	1
Feature 87	-	-	1	-	-	1
Totals	31	39	33	24	18	145

* Includes specimens collected from pit surfaces prior to trench excavation.

Raw materials employed as hammerstones include at least seven rock types (cf. Table 31). Quartzite specimens are most abundant (n=39, 27%), followed closely by rhyolite and basalt. Opalite hammerstones are relatively common (n=24, 17%), probably employed most frequently in expedient rough percussion tasks and/or the excavation of tuff layers overlying toolstone. Even given its tendency to fracture easily, opalite is an economical hammerstone alternative in a quarry setting; if the cobble breaks, it can be replaced easily at low cost.

The assemblage exhibits sizes ranging from small fist-sized cobbles that can be held and used with one hand, to large, two-handed implements, probably employed as "throw stones" (i.e., projectile hammer) in the removal of opalite from bedrock exposures (cf. Schmitt 1992b). Based on morphology and weight (range = 2600–4800 gm), seven throw stones were identified, all discovered in or adjacent quarry pits; some additional fragments (46% of the specimens are incomplete) may be spalls from these large hammers.

Shaped hammerstones (n=33) were recovered in various contexts. Although use-wear and fragmentation obscure some evidence of manufacture, most were shaped by pecking and abrasion (cf. Figure 46b) or bifacial flaking. Ten specimens were flaked bifacially along all margins to create thin, disc-shaped hammers (mean diameter = 12.5 cm; cf. Figure 46c). Although edge damage (spalling, crushing) indicates they served as hammerstones, they also may have served as excavation tools to remove tuff and other debris while isolating toolstone in bedrock exposures. Overall, shaping is most common on opalite hammerstones (n=17, 53%); in fact, most (71%) opalite specimens are shaped.

Unshaped hammerstones (n=85) commonly are ovoid or subrectangular hand-held cobbles (cf. Figure 46d), of shape and weight useful for toolstone acquisition and subsequent controlled flake removal without further modification. Most unshaped specimens are rhyolite (n=27), followed closely by quartzite (n=23) and basalt (n=16).

One specimen from the surface of Feature 72 is an unshaped basalt hammerstone with multiple, deep striations truncating cortex on all surfaces; these probably resulted from use in biface edge preparation during mid-to-late stage reduction (cf. Schmitt 1992b). Because most activities performed at Locality 36 were directed towards toolstone acquisition and early stage bifacial reduction, the paucity of other hammerstones exhibiting striations is not surprising; elsewhere at Tosawihi, we collected scratched and battered cobble tools from reduction and habitation features in the Eastern and Western Peripheries (cf. Schmitt 1989; 1992b).

We also recovered a fossilized shell (cf. brachiopodia) quartzite hammerstone fragment (Figure 47). This unique artifact was recovered from the surface of Trench 5 in quarrying debris adjacent Feature 42.

Discussion

The wealth of hammerstones recovered from quarry pits, adits, and reduction features at Locality 36 is predictable. Intrasite analyses are discussed in Chapter 10; regardless of context, the data revealed an heterogeneous mix of shapes, sizes, and raw materials. However, when comparing the Locality 36 assemblage to hammerstones recovered from the Eastern and Western Peripheries, some interesting patterns emerge relative to “function” and raw material selection.

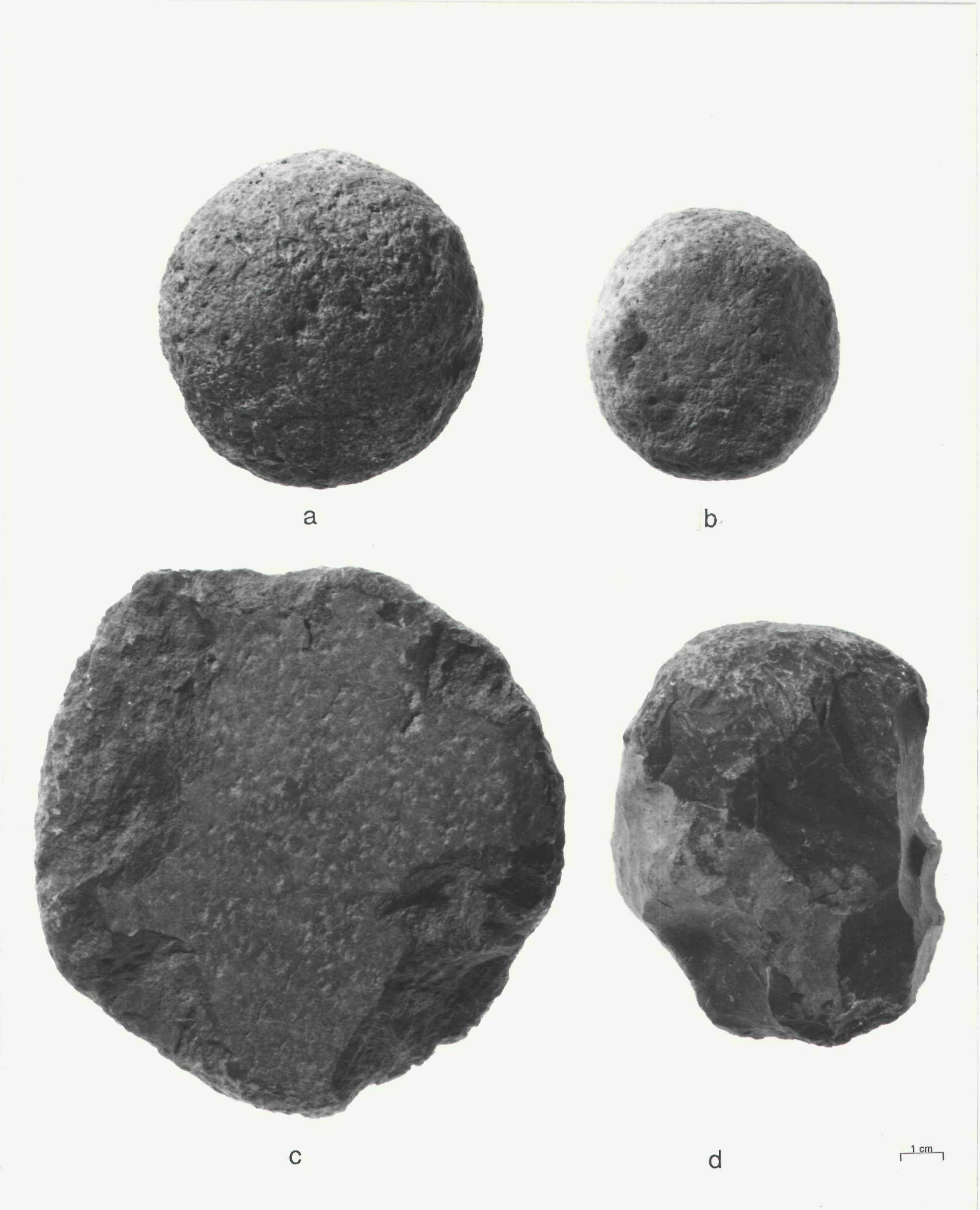


Figure 46. Selected hammerstones.

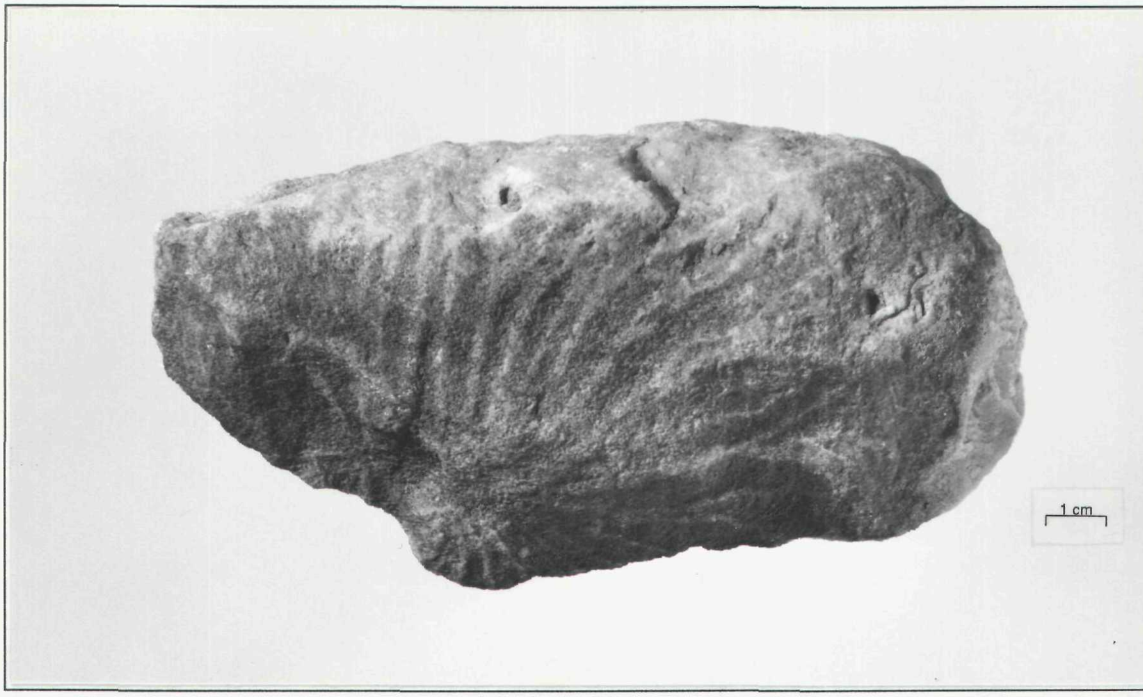


Figure 47. Fossilized (quartzite) cf. brachiopod hammerstone fragment.

Although hammerstones clearly were employed in percussion, most of it probably related to toolstone reduction, initial scrutiny of the Locality 36 specimens found them more massive than hammerstones recovered elsewhere in the Tosawihi vicinity. In order to evaluate our assumptions quantitatively, we calculated mean weight per item for complete specimens in order to compare them to hammerstone assemblages from the Eastern and Western Peripheries (cf. Schmitt 1992b; Appendix I). The results (Table 32) support our initial assumptions; on the average, hammerstones from Locality 36 are twice as heavy as those recovered from non-quarry sites. Although some Locality 36 specimens are small and shaped (probably employed in late stage, controlled flake removal), and some specimens peripheral to 26Ek3032 are large cobbles from quarry contexts, the overall abundance of large hammerstones at Locality 36 reflects functional differences. This conclusion is supported by data from investigations at other quarry sites in the Tosawihi area (Elston, Raven, and Budy 1987, Elston and Raven 1992, Leach and Botkin 1991, 1992). The mean weight of hammerstones recovered from these sites is much higher than those from the predominantly non-quarry sites of the Eastern and Western Peripheries and the Northern Corridor (Table 32). Specifically, smaller hammerstones found peripheral to the quarries signal use in late stage controlled flaking, while the large Locality 36 specimens and those from other quarry sites apparently were employed in toolstone acquisition and subsequent early stage reduction.

Table 32. Mean Weight/Item of Complete Hammerstones by Subarea.

	No. Complete Hammerstones	Mean Weight (g)/Item
Locality 36	78	968.9
Western Periphery	33	547.2
Eastern Periphery	28	508.2
Northern Corridor	6	406.1
87-89 Quarry Sites	17	755.8

These data are consistent with observed patterns of biface reduction. Biface and debitage studies (Bloomer, Ataman, and Ingbar 1992; Bloomer and Ingbar 1992) indicate that early stages of biface reduction were conducted at or adjacent quarries, while increasingly later stages of reduction took place with increasing distance from quarries.

Elsewhere, Schmitt (1992b) examined hammerstone material type from two areas peripheral to the center of the Quarries and found each to contain higher frequencies of locally available rock types suggesting most were acquired from nearby drainages and/or outcrops. As presented in Figure 48, material types in the assemblage from Locality 36 are distributed more evenly than in the eastern area (Eastern Periphery), where quartzite dominates the assemblage, or the western area (Western Periphery), where basalt dominates. This pattern suggests that hammerstones used at Locality 36 were collected throughout the region in logistical forays, while camping at peripheral water sources, or while en route to the quarries. Quarriers may have favored certain materials for use in certain tasks (i.e., extraction versus controlled reduction/ thinning; cf. Chapter 10). Temporal patterns of such preferences are not evident in our assemblage.

Metates

Five fragmentary metates were recovered from surface contexts. Two were collected as extra-feature isolates in the northern portion of the site amid numerous reduction features. Manufactured on a large basalt tabular cobble, one displays moderate use-wear (polish and striations) on both planar surfaces (Table 33). Another is a welded tuff metate with pronounced polish and striations on its concave working surface; numerous pits truncating the working surface reflect resharpening.

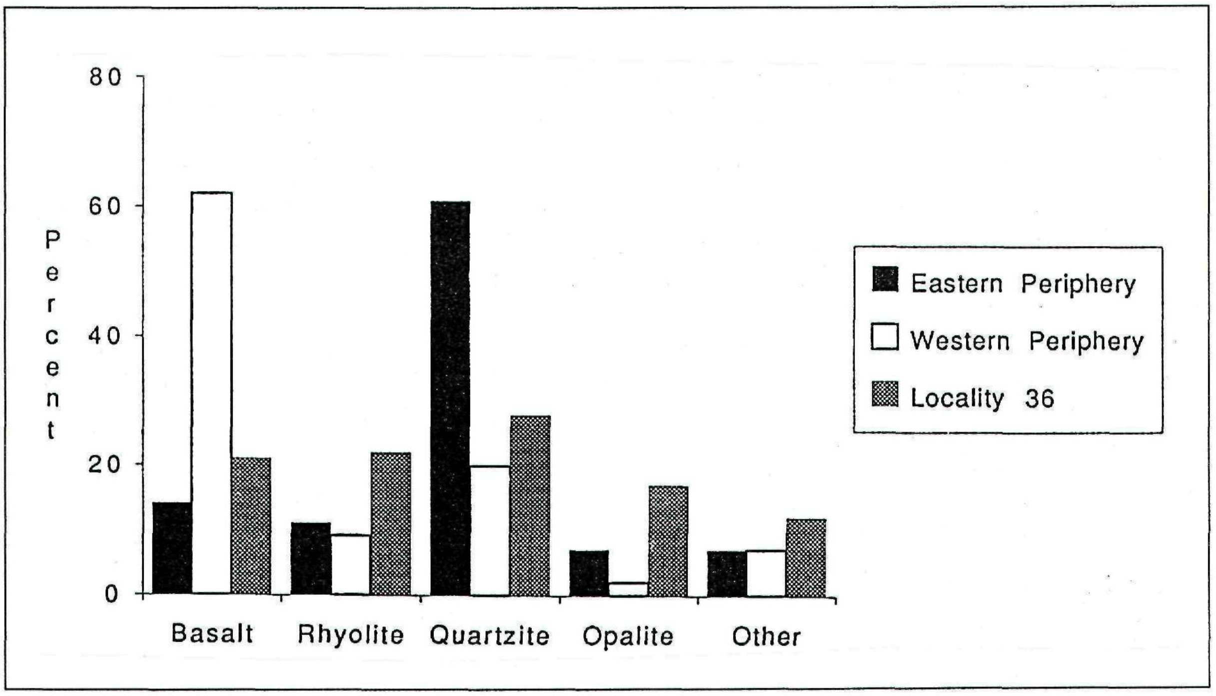


Figure 48. Proportions of hammerstones by material type and area.

Table 33. Provenience and Attributes of Various Artifacts, Locality 36.

METATES

Specimen No.	Fea.	Material	Plan Outline	Facial Use	Use Surface Profile	Use Wear	Length (cm)	Width (cm)	Thickness (cm)	Wt. (g)
01-3	-	Basalt	SR	B	PL	M	28.3	14.0	4.6	2475.2
01-4	-	Tuff	IN	U	CN	H	17.0	12.3	4.4	376.3
3063-2	63	Tuff	OV	U	CN	M	33.5	18.4	7.4	3000.0
3069-2	69	Sandstone	SR	U	PL	M	7.0	5.8	1.5	71.9
3086-2	86	Rhyolite	TR	B	PL	M	30.4	23.5	7.2	4000.0

BONE ARTIFACTS

Specimen No.	Trench	Fea.	Depth (cm B.S.)	Species	Element	Length (cm)	Width (cm)	Thickness (cm)	Wt. (g)	Type
2599-101	1	103	85	*Bison bison*	Thoracic spine frag.	25.2	4.8	1.7	109.7	WE
2599-108	7	103	84	cf. *Cervus elaphus*	Antler frag.	20.6	5.8	3.5	163.3	WH
2599-156	3	49	78	Artiodactyla	Rib or spine frag.	6.4	2.8	1.8	5.4	UN
2599-166	3	49	100	Artiodactyla	Rib frag.	-	-	-	2.7	UN
2599-217	5	-	6	Artiodactyla	--	5.5	1.5	0.6	4.5	WE

OTHER ARTIFACTS

Specimen No.	Trench	Fea.	Depth (cm B.S.)	Material	Length (cm)	Width (cm)	Thickness (cm)	Wt. (g)	Type
2599-182	3	49	130	Basalt	15.5	4.7	2.5	342.6	WE
2599-202	4 ca.	22	10-40	Tuff	2.6	2.4	2.3	11.6	SE

Key:

Plan Outline
SR = Subrectangular
OV = Ovoid
TR = Triangular
IN = Indeterminate

Facial Use
B = Bifacial
U = Unifacial

Use Surface Profile
PL = Planar
CN = Concave

Type
WE = Wedge
WH = Wedge/Hammer
SE = Sphere
UN = Unknown

From the surface of Feature 63, we retrieved two fragments of thick, welded tuff ground stone exhibiting moderate surface fatigue (cf. Table 33); use-wear is most pronounced within a circular, slightly concave (diameter ca. 12 cm) polished and striated facet; the piece may have served as an expedient mortar (cf. Schmitt 1992c). From Feature 69 we collected a thin milling stone fragment with unifacial use-wear. Although fragmentary, it appears shaped and may represent a small, portable metate or palette used with a pebble-sized handstone (cf. Juell 1990; Kramer and Thomas 1983). Finally, a thick rhyolite metate fragment was discovered at Feature 86; it weighs more than 4000 grams and exhibits extensive bifacial use.

Bone Artifacts

Four artiodactyl bone fragments and a proximal antler fragment were collected from backhoe trenches. In Feature 103 (Trench 1), we recovered a bison thoracic spine from Stratum 14 (cf. Table 33). Although its dorsal end exhibits no use-wear (i.e., it is fragmentary; Figure 49a), the articular process of its ventral surface is rounded from "hands-on" use, suggesting that the dorsal end served as the working end, probably employed in tuff excavation and/or as a wedge. Investigations at Feature 103 (Trench 7, Stratum 12) also discovered a large, artiodactyl (cf. *Cervus elaphus*) antler fragment (cf. Table 33, Figure 49b). Both ends exhibit use-wear (the distal end is scarred and rounded, and the horn core is battered), suggesting use as an excavation tool and as a billet; we recovered a remarkably similar artifact from Locality 23 (Schmitt 1992a).

Two highly fragmentary large mammal bones were recovered from deposits adjacent the Feature 49 adit. Although they lack evidence of use and may simply represent subsistence residues, their context suggests that they probably served as quarrying implements (e.g., wedges and/or digging tools); our investigations at a number of sites in and adjacent the quarries have yet to identify "food bones" in quarry contexts (cf. Leach and Botkin 1991; Schmitt 1992a).

The remaining bone artifact is a small wedge collected from Trench 5 (cf. Table 33; Figure 50). Manufactured on an unidentified large mammal bone, both ends display modification; the proximal end is rounded and faintly battered, and the other is beveled to a chisel-like working edge (cf. Figure 50). While conducting quarrying experiments at Locality 36, Carambelas and Raven (1991) employed similar (wooden) wedges and found them useful in isolating and extracting toolstone, especially to loosen blocks of opalite in bedrock exposures.

Other Tools

Five distinctive tabular basalt tools were recovered from Locality 36. On the basis of use-wear analysis, provenience, and results of actualistic experiments, we infer that they served as wedges in quarrying.

Each is made of platy andesitic basalt which weathers into elongated triangular or rectangular tabular fragments, as much as ca. 50 cm long in their natural state (Figure 51). All of the tools are considerably shorter (Table 34) and probably represent distal end fragments. Two appear to have been used after breakage. They evidence bipolar battering, suggesting their use in an indirect percussion technique. Three specimens exhibit small impact scars in addition to the battering present on all specimens.

Table 34. Dimensions of Basalt Quarrying Tools.

Specimen No.	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)
2599-182	15.5	5.1	2.1	342.6
2599-361	13.8	7.5	1.8	227.0
2599-362	8.4	7.5	2.6	288.5
2599-363	21.5	6.8	2.1	523.5
2599-364	12.3	6.7	1.9	221.2

Figure 49. Selected bone artifacts.

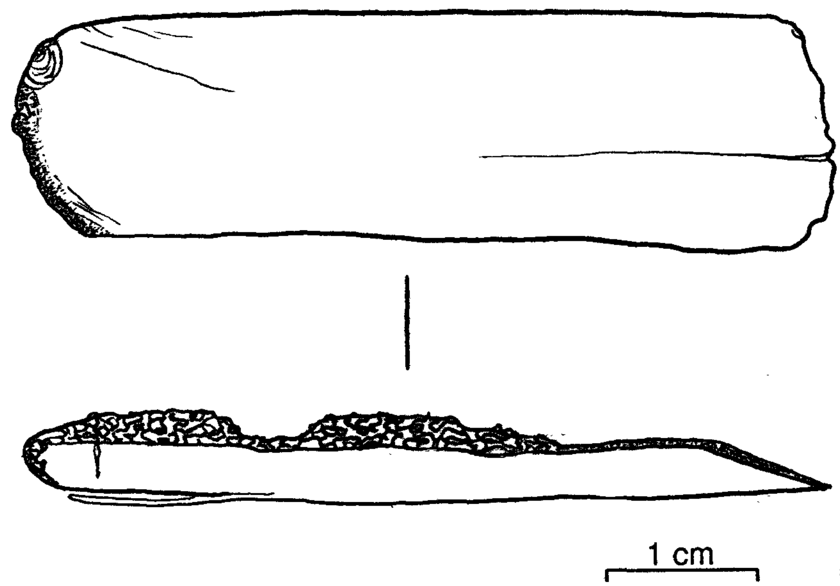


Figure 50. Split bone wedge.

One piece is very similar to another basalt tool recovered from quarry contexts during previous fieldwork at Tosawihi (Ataman 1992:Figure 49a). Both are roughly triangular in shape, of similar size, with battering on either end and tuff embedded in the battering scars on at least one end.

The context of each of the five tools reflects their quarry-related function. Four were recovered from the backdirt overlying the several quarry pits exposed in Trench 3, and one was found *in situ* within the adit there (cf. Chapter 8). Basalt does not occur naturally at Locality 36, and thus was transported to the site, presumably to be used in quarrying.

Although references to the use of stone axes and picks for toolstone extraction are not uncommon in quarrying literature (Wilson 1897; Holmes 1919; Lewenstein 1987), discussions of stone wedges are relatively rare. A few correlates to archaeological specimens from Locality 36 are cited in experimental quarrying studies. Basalt implements were used effectively as wedges for toolstone extraction by Carambelas and Raven (1991) in quarrying experiments at Tosawihi. In these experiments, a basalt wedge was inserted into a crack in the opalite bedrock and tapped lightly with a hammerstone to free a piece of toolstone from surrounding bedrock. A chert wedge was used for removal of overburden and toolstone extraction in a quarrying experiment by Greiser (1983).

The remaining artifact is a tuff sphere ("ball") from Feature 22 of Trench 4 (cf. Table 33). Measuring approximately 2.5 cm in diameter, it exhibits faint overall polish and a few manufacture striations; it may represent an ornamental preform, or perhaps an expedient, non-functional curiosity.

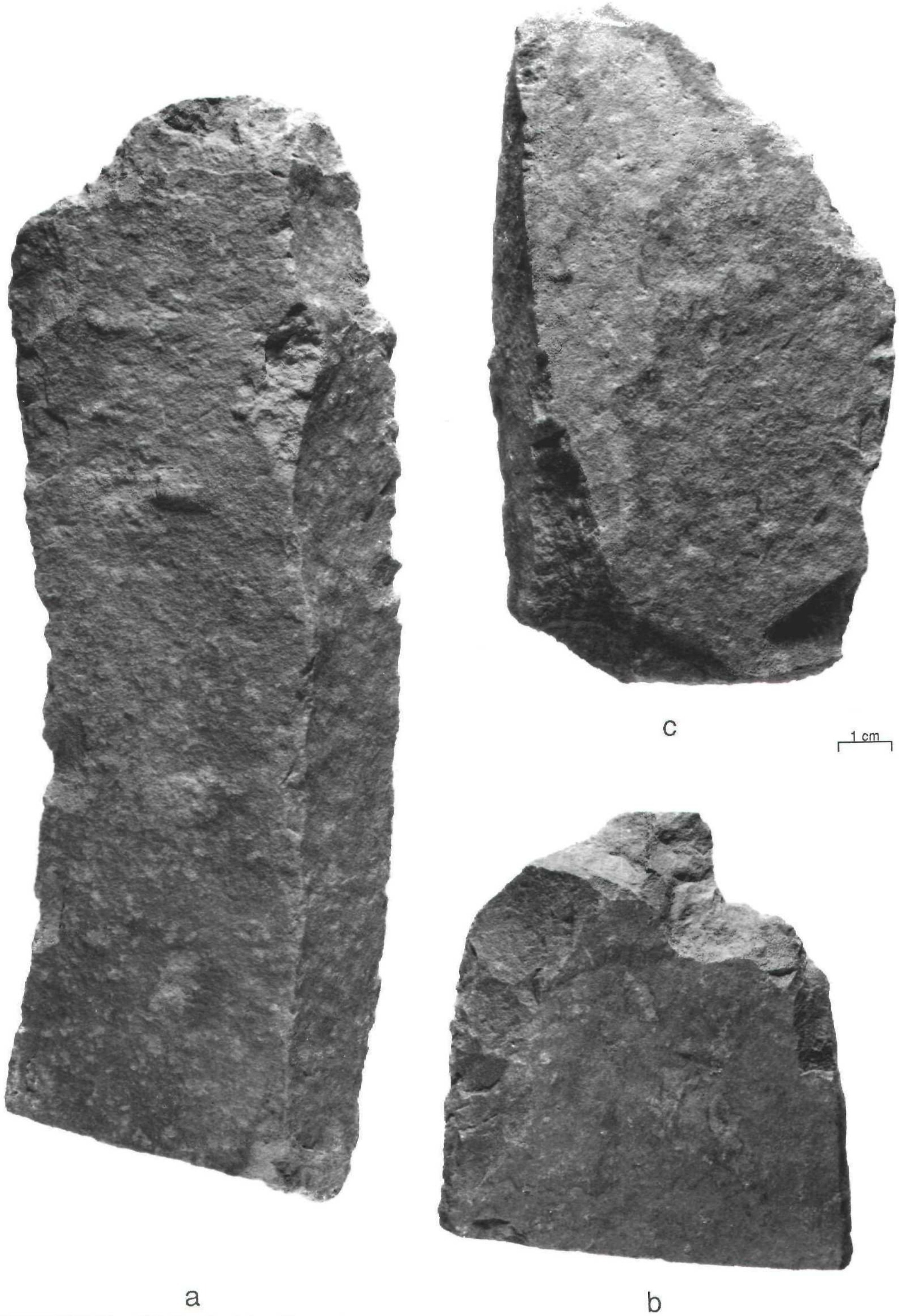


Figure 51. Basalt quarrying tools.

Chapter 7

BEDROCK GEOLOGY, GEOMORPHOLOGY, AND SITE FORMATION PROCESSES

Daniel P. Dugas and Robert G. Elston

In this chapter we describe the surface morphology and bedrock geology of Locality 36, and outline changes in geomorphology resulting from cultural modifications. The occurrence of toolstone is determined by geological forces; the benefits and costs of extraction and processing it are influenced strongly by the type of stone available, its quality, and the degree to which natural forces of faulting and erosion have shaped it and made it accessible. Since these factors also constrain the possible approaches to quarrying, variability in bedrock morphology should be accompanied by variation in quarrying techniques and their effects on both bedrock and overlying soil and clastic material.

The Shape of the Quarry

The site is situated on a ridge formed on a bedrock core of Tertiary volcanics (Figure 52). The ridge top is relatively flat, with increasingly steep slopes on the east, south, and west. Quarry pits and processing debris are concentrated in a band about 30 m wide running northwest-southeast along the upper western and southwestern slopes. Three large groups or clusters of quarry pits are designated Areas A, B, and C (Figure 52).

The Tertiary volcanics contain roughly horizontal to slightly eastward dipping, bedded airfall and waterlain tuffaceous deposits (Figure 53). A zone or "cap" (Bartlett, Enders, and Hruska 1991; Elston 1992a:Figure 20) of this material several meters thick was silicified by hydrothermal activity propagating horizontally along bedding planes and joints. The silicified zone contains beds and stringers of chalcedonic opalite ranging from 5 cm to at least 80 cm in thickness, and from a few centimeters to scores of meters in lateral extent. The opalite is frequently inclosed by unsilicified or partially silicified tuff, or brittle opal. Above the silicified tuff lies up to 80 cm of unsilicified tuff. The reddish silty clay of a well developed B soil horizon lies on tuff and opalite bedrock, below eolian silts and silt loams of the modern soil surface. Sands and gravel of a remnant Pleistocene terrace occur northeast of the main concentration of quarry pits (cf. Figure 52), as well as various sediments and debris resulting from disturbance of the natural surface cover and bedrock during prehistoric quarrying.

Three slope regimes prevail on the ridge (Figure 53): the flat surface of the ridge top, a moderate slope, and a steep slope. The flat surface conforms to the planar, silt covered surface of the uppermost tuff unit. Between the flat surface and the steep slope, the moderate slope (where soils are thinnest and quarry pits are concentrated) is formed by the partially eroded edge of the silicified zone. The steep slope is the result of faster erosion of the softer tuff below the silicified zone.

The silts and silt loams of the modern surface are thickest (over 60 cm in the Trench 2 exposure) nearest the ridgecrest and the upper northeastern hillslope flank. This pattern of silt deposition on hillslopes to the lee-side of the prevailing wind has been noted in several locations in

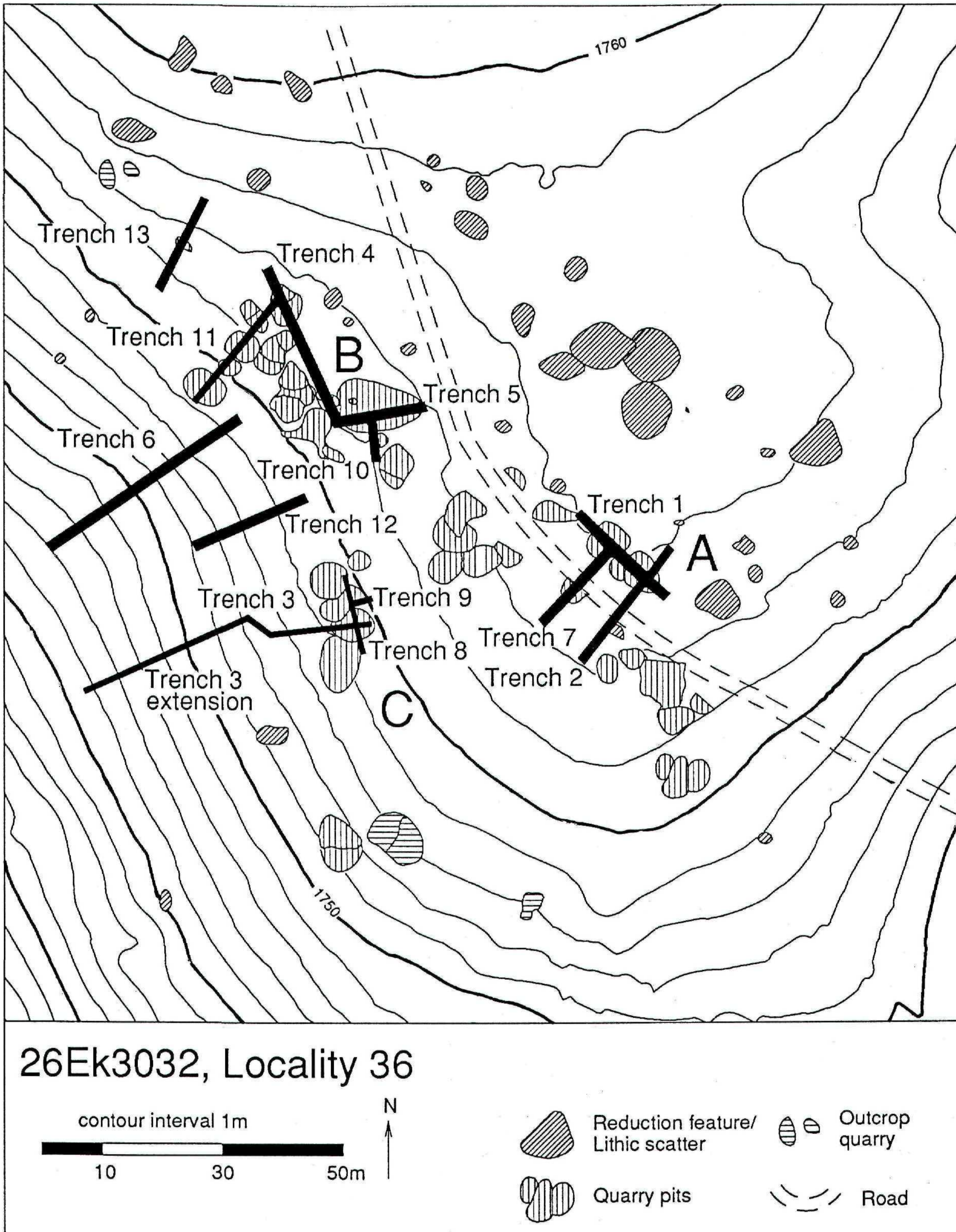


Figure 52. Quarry pit complexes and backhoe trenches.

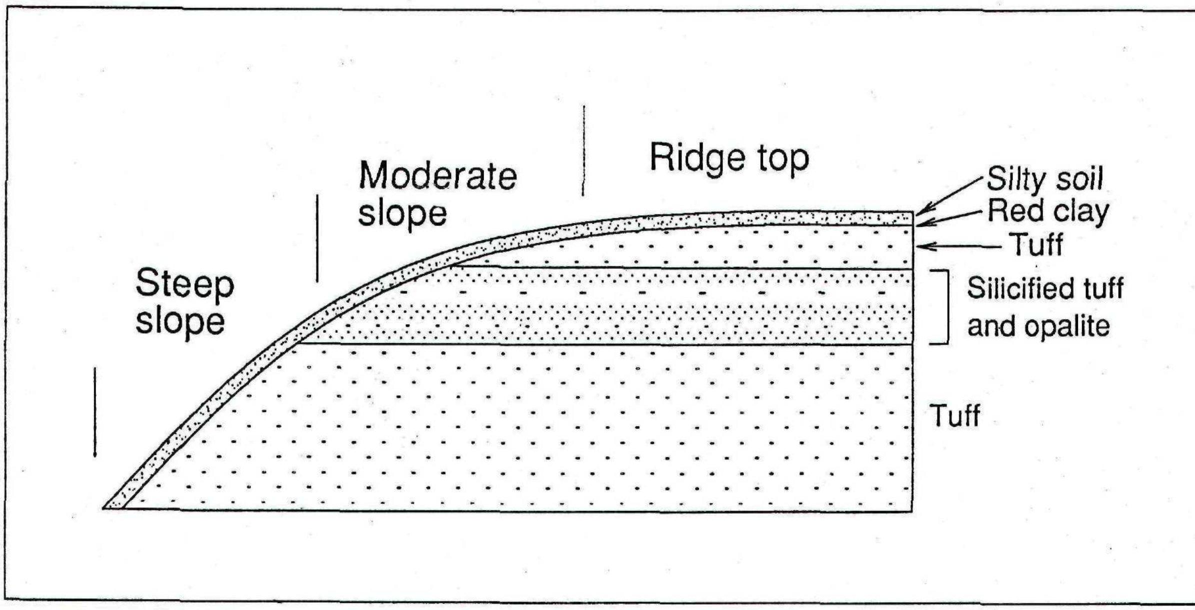


Figure 53. Schematic cross-section of Locality 36, looking north.

the Tosawihi area (Elston and Raven 1992). Significant eolian transport and redeposition of these silts may still be occurring, as evidenced by the burial of quarry pits and hearth features by silt in flat-lying areas on the ridgecrest and just to the east of it in Area A. Radiocarbon dates from these hearths indicate that as much as 30 cm of silts have been deposited between 410 and 150 years ago.

The buried red clay B horizon is most extensive on the southwest aspect slope below the ridgecrest. We assume this horizon has been developing at least since the end of the Pleistocene, but it possibly is much older. It tends to be thinnest to the north, becoming thicker downslope and to the southeast. This trend seems to be related to the greater proportion of tuff bedrock compared to opalite in this general direction. Presumably, weathering of tuff is faster and produces more clay than does weathering of opalite. This apparent relationship of bedrock type to soil development was noted in detail in the soil profile of Trench 6 (cf. Chapter 8).

Bedrock is most accessible where exposed at the surface and where overlying deposits are thinnest. At Locality 36, this condition prevails in Area B where the moderate slope intersects the edge of the silica cap. Here, most of the upper tuff has been removed by erosion and clay and silt soil cover is thinnest. Erosion of surface sediments by slopewash and soil creep is most intense where the relative lack of sediment-trapping vegetation probably prevents the accumulation of eolian deposits or sediments eroding from the flatter portion of the site. Small, poor quality opalite outcrops occur at the northern and southern ends of the locality. These are battered but not quarried, suggesting they were tested from time to time but found wanting. Under pre-quarry conditions, other opalite outcrops may have been present as well. Thus, the original discovery of quarryable opalite at Locality 36 is not surprising.

Types of Quarry Settings

Bedrock morphology influences the costs of toolstone extraction and hence the quarrying strategies that can be utilized profitably. Bedrock settings at Tosawihi can be idealized as three types

(Elston and Dugas 1992), depicted schematically in Figure 54. As discussed below, two of these settings were at Locality 36, and the third may have been present prior to landscape modification brought about by aboriginal quarrying. Detailed stratigraphic descriptions of select backhoe trenches are offered in Chapter 8.

In Type 1 morphology, toolstone is exposed at the surface in a ledge or outcrop (Figure 54a), and its presence is obvious. Such settings are common at Tosawihi along fault scarps above steep slopes and in stream cuts. In both situations, geological processes (gravity and water) transport weathered debris away from the outcrop and prevent its burial. Quarrying proceeds in a Type 1 situation by clearing weathered rock and removing fresh material from the outcrop, working it back into the slope (e.g., site 26Ek3208; cf. Leach, Dugas, and Elston 1992). This may be accomplished by undermining at points where beds of weaker rock underlie more massive rock; frequently this technique creates a short tunnel or adit. Work also may proceed laterally, back and forth along the face of the outcrop; if the face is large enough, more than one area can be worked simultaneously. No outcrop presently visible on the surface of Locality 36 has been quarried, but it is possible that some Type 2 settings once had Type 1 morphology (surface outcrops) removed through quarrying or buried by quarrying debris.

In Type 2 settings, more or less horizontal beds of toolstone are intersected by a sloping surface (Figure 54b). Because of the slope, gravity and water transport may prevent burial of the toolstone by *deep* accumulations of soil and colluvium. Although the bed does not quite outcrop at the surface, the presence of subsurface toolstone will be signaled by toolstone clasts in colluvium on the slope below the bed. Type 2 settings usually are worked into the slope of the hill, with lateral movement along the face of the ledge; adits may be created where possible. Type 2 morphology is common across the lower portion of the moderate slope, particularly in Area C.

Type 3 morphology occurs where the toolstone stratum parallels the present ground surface, but is buried by soil and colluvium (Figure 54c). Type 3 settings usually are quarried by

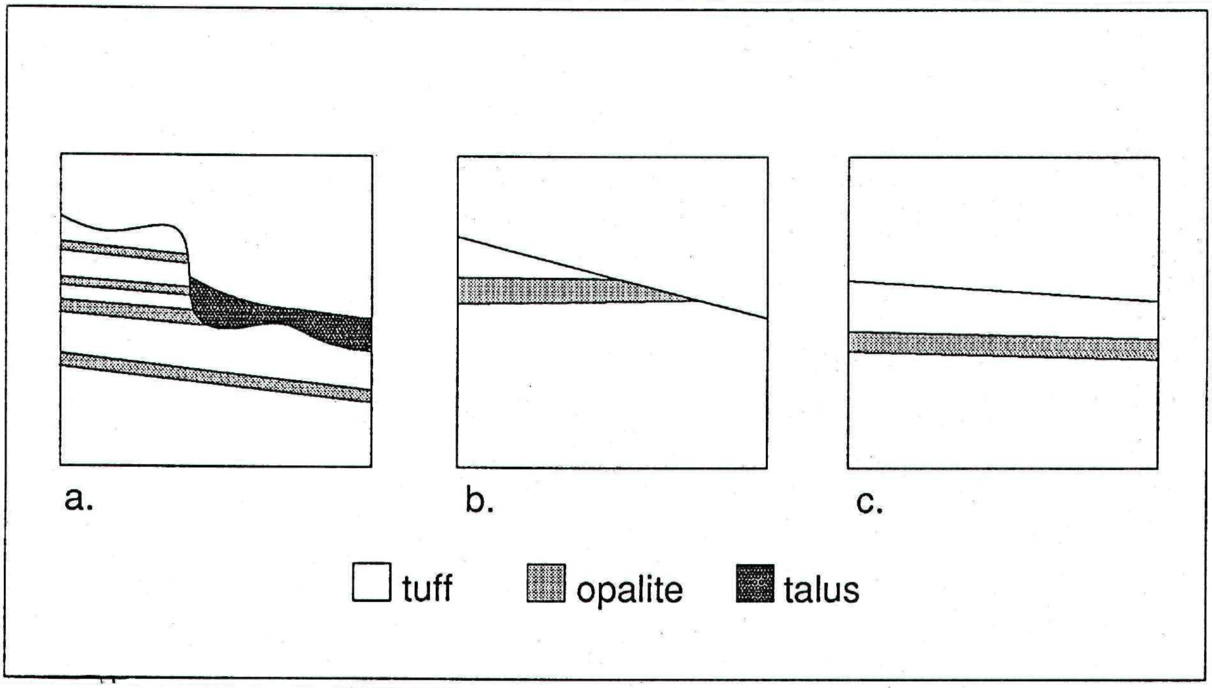


Figure 54. Morphologies of opalite occurrence. a. Type 1: surface outcrop; b. Type 2: intersected by surface slope; c. Type 3: parallel to surface.

excavating vertical pits. Where there is slope, work tends to proceed uphill, but lateral movement in any direction is possible, and coalescing pits may result in either a broad, saucer-shaped pit (e.g., Feature 7, 26Ek3171; cf. Botkin, Dugas, and Elston 1992) or a crude planing of the bedrock surface. At Locality 36, such settings are found in the upslope portions of Areas A and B just either side and along the flat top of the ridgeline where bedrock lies horizontal or at a low-angle dip to the east. The Type 3 setting grades into Type 2 downhill as the increasing angle of the slope intersects horizontal bedrock.

Spatial Variation in Cultural Modification of Bedrock

Because of variation in the bedrock setting, the quarrying strategies utilized at Locality 36 also vary. In the Type 3 settings of Areas A and B, quarrying progressed vertically downward through overlying soil, then laterally across the opalite and tuff bedrock creating broad pits. Within these occur numerous smaller pits excavated deeper into places of higher quality opalite (and where jointing in the opalite favored easier extraction). Although there seems to have been a general tendency to work into the slope, the surface of Area B in particular was cratered with a welter of intersecting pits and berms in no discernible pattern, and the bedrock is crudely planed, suggesting that quarrying moved laterally in all directions. In the Type 2 settings of Areas B and C, the tendency to work into the slope, or laterally along a bedrock ledge, is expressed more strongly and is obvious in profiles presented in the following chapter.

Where there was a change in bedrock morphology between Types 2 and 3, (as in Areas B and C), the approach to quarrying shifted as well. For instance, along Trench 4 in Area B, there is a north to south transition from lateral planation of the bedrock, to broader pit-like quarrying, then to the utilization of higher relief faces and deeper pits and adits.

We note also that quarry debris and other sediments capping the bedrock become thicker and the bedrock surface slopes considerably down to the southeast through Area B, forming a broad depression. Although it is unclear whether the slope was created by quarrying or is a natural feature, this depression has been filled with a significant amount of quarry debris. Its lowest observed point lies at the intersection of Trenches 5 and 10 in the south side of Area B. Here, a combination of lateral pitting, rough planing, and adit excavation has created an elongate pit in the opalite bedrock some 3 m wide and at least 1.7 m long. When exposed by the backhoe, this pit was filled with water to a depth of 50 cm; in fact, lesser amounts of water trapped in bedrock pits and adits were observed in several places at Locality 36. That bedrock quarry features can function as cisterns for water collection and storage suggests that strategies for positioning people and procuring resources at Tosawihi might have changed as development of the quarries progressed through time.

Although lateral pitting and planing are dominant along Trench 4, it also is evident that a low relief face of tuff and opalite was worked uphill in a combination of small pits and adits. Small adits exposed at the junction of Trenches 4 and 5 and at the south end of Trench 10 indicate that some pits were expanded laterally when the possibility of isolating an overhanging opalite segment materialized. The small scale and rarity of adit features in this Type 2 setting of Area B, however, suggests that large outcropping opalite ledges underlain by softer tuff were not always present, providing infrequent opportunities for the formation of adits. It is possible, however, that extensive quarrying removed any outcropping ledges.

It is likely that a Type 1 setting was once present in Area C, with a bedrock ledge exposed at the surface prior to quarrying. A series of rubble-filled quarry pits were revealed by trenching to be aligned along a ledge of massive opalite underlain by highly fractured opalite and tuff. This ledge is several meters long and arcuate (convex uphill), with a large adit quarried under it. The adit and other overhangs in the bedrock were filled and covered with quarry debris and slopewash, although the overlying material is very thin in places. The upper surface of the bedrock appears to be weathered, with a yellowish patina and abundant fine cracking and jointing. At other Tosawihi locations where bedrock currently is exposed as surface ledges, opalite overhangs are common above negative-relief weathered tuff beds.

Quarrying along this ledge is likely to have concentrated first on the removal of weathered materials from the surface of the outcrop, followed by working back into and laterally along the freshly exposed opalite face, isolating opalite overhangs by removing softer tuff beds below and above them.

A buried quarry feature not visible on the surface occurs in Trench 3 several meters down slope from the large adit. The feature is isolated from the adit and associated pit features by a segment of un-quarried bedrock and overlying surface sediment; the quarrying activity in each area is unrelated, and was separated by several thousand years of time. The buried quarry feature is one of the earliest at Locality 36 (cf. Chapter 8). It was produced mainly by working low relief faces, concentrating on two or three isolated lenses of opalite within massive tuffs. Currently, the opalite bedrock is more than a meter below soil and colluvium in a Type 2 setting, but whether or not it was exposed at the surface in the past is uncertain. Once buried by colluvial processes, it apparently was forgotten.

In the following chapter, we describe the stratigraphy and chronology of subsurface features.

Chapter 8

STRATIGRAPHY AND CHRONOLOGY

Robert G. Elston and Daniel P. Dugas

The natural and cultural deposits of Locality 36 preserve a record of quarrying and other cultural activity, and the timing of events is measured by radiocarbon dates. These data contribute to local and regional culture history, but they are more interesting viewed from the theoretical questions raised by the benefit/cost model of economic behavior presented in Chapter 1. The model predicts that quarriers first should pursue toolstone in places where the presence of quarryable toolstone is evident from surface indications, where extraction costs are lowest, and where toolstone quality is sufficient to insure profitable returns from search and extraction. Only thereafter, should quarriers ply toolstone "patches" that are increasingly difficult to find and expensive to quarry. Different bedrock settings were described in the previous chapter and evaluated with respect to the costs of toolstone extraction. Type 1 settings (surface outcrops) are found easily and, toolstone quality being equal, are the least expensive to exploit. Since Type 1 settings were not quarried at Locality 36, we can assume that the quality of toolstone they offered was too poor to yield adequate returns. Type 1 settings may have occurred originally at Locality 36, being destroyed by subsequent quarrying; aspects of this question are explored below and in the following chapter. The description and analysis of the stratigraphic and radiocarbon record presented here focuses on tracing the progress of quarrying at Locality 36 through time and space. Chapter 9 explores how bedrock topography affected methods of extraction; Chapter 12 examines how intensity of quarrying varied in response to toolstone quality and ease of extraction.

Stratigraphic Nomenclature

Investigations in the Tosawihi Periphery suggest that similar quarry and processing deposits tend to appear in a few recurrent situations (Leach, Dugas, and Elston 1992; Botkin, Dugas, and Elston 1992). Coarse units in which pieces of rock lie on or against one another, with open spaces between the clasts, are characterized as *open framework*. Open framework is divided into *poor, moderate,* or *typical* depending on the relative amount of open space and finer matrix present. When finer matrix is abundant and the larger clasts do not rest on one another, the deposit is *matrix supported. Hash* is a deposit of very fine opalite chips and chip-like fragments mixed with fine-grained materials such as pulverized tuff, silt, and clay, usually found in contact with bedrock in the bottoms of quarry pits. In experimental quarrying, primary deposits of hash were produced on quarry pit floors by battering bedrock with hammerstones during extraction. We also observed the formation of hash when rain washed coatings of dust off pit walls and large clasts to accumulate in pit bottoms.

Typical quarry deposits are comprised of coarse units (mostly tuff and opalite chunks and debitage) alternating with layers of fine sediments. The coarse units probably represent episodes of quarrying and processing that accumulated instantaneously in archaeological terms. Fine-grained strata other than hash, and some matrix supported strata, more probably were created by natural processes (ie., colluviation, slopewash, eolian accumulation, and infiltration) over longer periods when quarrying was not active. Greater compaction and signs of weak soil development (increased carbonates and phosphorous, decreased iron and aluminum) in older deposits and in fine strata underlying truncation surfaces suggests that some surfaces were stable through relatively long intervals (Leach, Dugas, and Elston 1992).

In some cases, strata can be grouped into major *horizons*, each a time-stratigraphic unit comprised of one or more strata. Horizon boundaries are indicated by surfaces formed on truncated strata of the underlying horizon, each truncation surface marking an episode of human excavation. Layers of sediment comprising the subsequent horizon are usually internally conformable (oriented with relation to the same grade), but unconformable on, and often inset into, earlier deposits. Coarse and fine-grained sediments within horizons may indicate episodes of quarrying and processing alternating with intervals of inactivity, but each horizon represents a period dominated by deposition. While horizons appear to represent piles of debris created during extraction and processing from a pit at one location, horizon boundaries seem to be created when quarrying excavations are moved laterally into old debris, or during vertical re-excavation of an old pit. That truncation surfaces often may have remained exposed for extended periods is suggested by signs of weak soil development (described above) with which they are sometimes associated. Horizons seldom can be correlated between trench exposures; their value is to group sets of local strata.

We begin the discussion by listing all the radiocarbon dates from Locality 36 (Table 35). We then briefly discuss the dates from the Ridge Top hearths, and describe the natural profile of the unquarried area in that vicinity. Stratigraphic descriptions of the three subareas (A, B, and C) described in the previous chapter (cf. Figure 52; Figure 55) follow; each was sampled by intersecting backhoe trenches. The ridge crest was sampled with 1 m x 1 m excavation units, and the upper 30 cm of silts were removed with a road grader in small increments. Quarry Area A occupies the southeastern portion of Locality 36 nearest the crest of the ridge where silty soil is deepest, and was sampled by Trenches 1, 2, and 7. In Quarry Area B, Trenches 4, 5, 10, and 11 reveal sediments over bedrock ranging from a very thin silt and red clay veneer to a moderately thick silt with a clay B horizon. Quarry Area B trenches also exhibit a sediment deposition and quarrying style transitional between Areas A and C. Quarry Area C is located slightly downhill between Areas A and B. Here, Trenches 3, 8, and 9, display the most clay-rich quarry debris and the most extensive adit quarrying of all three areas. In addition, Trench 6 was excavated to provide a view of the culturally undisturbed, natural soil profile on the steep slope below the quarry areas.

Tables of formal stratigraphic unit descriptions are provided in Appendix D. For the sake of simplicity, wall profiles are named by their dominant cardinal face (north, west, south, east).

Radiocarbon Dates

Radiocarbon dates from Locality 36 are summarized in Table 35 below. Dates are referred to by their lab numbers throughout the following discussion.

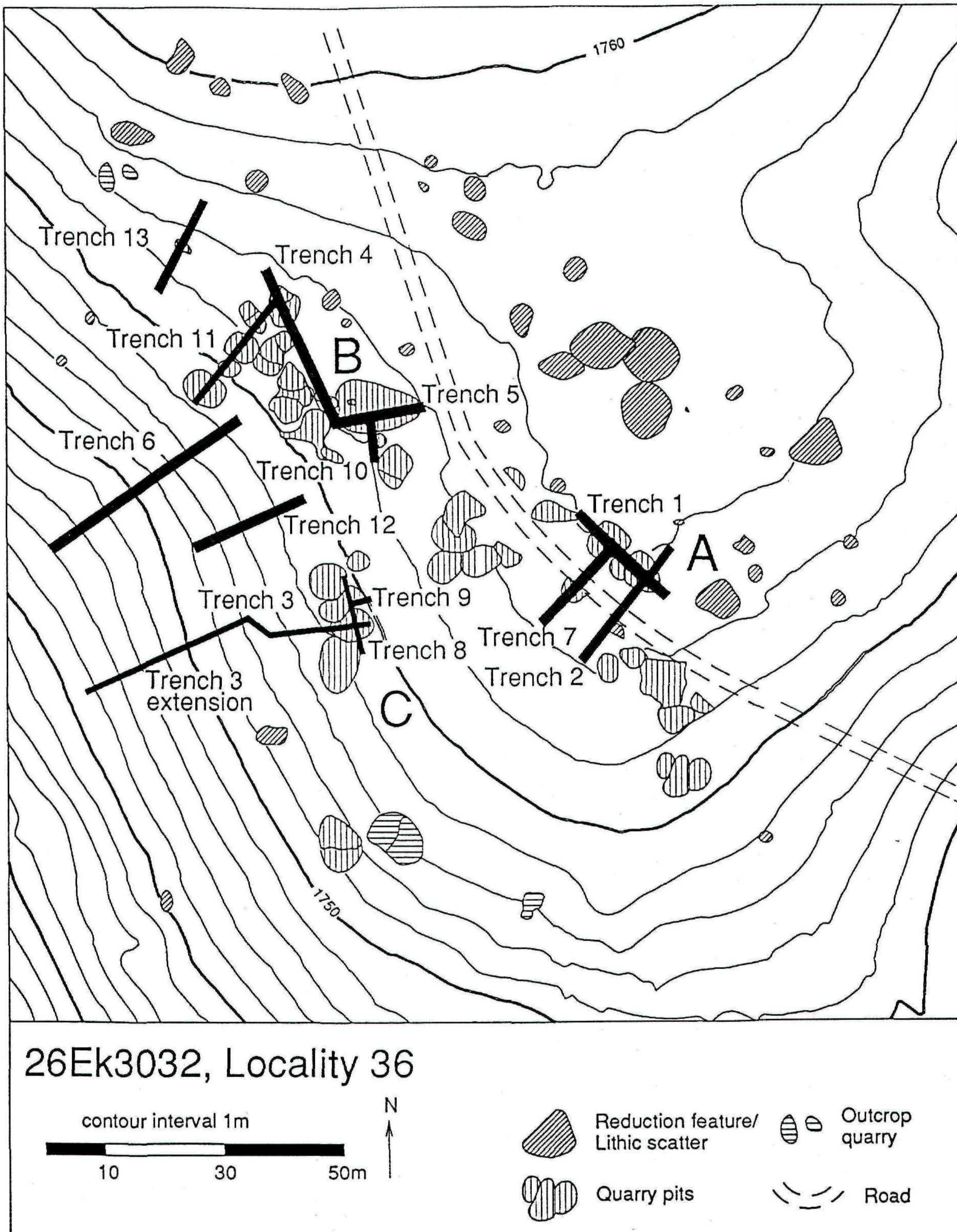


Figure 55. Features and backhoe trenches.

Table 35. Radiocarbon Dates From Locality 36, 26Ek3032.

Lab No.	Sample No.	Area	Trench/Wall	Feature	Unit	Date, B.P.
Beta-39485	2599-168-45	C	3, West	102	46	3890±60
Beta-42474	2599-160-7	C	3, North	102	44	3810±60
Beta-42475	2599-161-8	C	3, North	102	35	3830±80
Beta-42476	2599-162-9	C	3, North	102	42	3670±90
Beta-42477	2599-107-15	A	2, North	72	23	310±70
Beta-42478	2599-109-16	A	7, North	71	15	370±50
Beta-42479	2599-110-17	A	1, bottom	104	n/a	170±60
Beta-42480	2599-112-19	A	7, North	71	17	390±60
Beta-42481	2599-113-20	B	11, bottom	11	n/a	230±70
Beta-42482	2599-201-21	B	4, West	22	28	720±60
Beta-42483	2599-205-22	B	5, North	42	25b	550±80
Beta-42484	2599-207-24	B	5, North	42	31	620±90
Beta-42485	2599-211-28	B	4, bottom	27	n/a	190±50
Beta-42486	2599-213-30	B	5, bottom	42	n/a	690±90
Beta-42487	8001-1-31	Ridge		105	n/a	330±50
Beta-42488	8041-1-33	Ridge		106	n/a	410±60
Beta-42489	8081-1-35	Ridge		107	n/a	280±50
Beta-42490	8161-1-40	Ridge		109	n/a	310±60
Beta-42491	8201-1-42	Ridge		110	n/a	150±70
Beta-42492	2599-165-44	C	3, South	49	99/108	570±60
Beta-42493	2599-176-47	C	8, East	49	104	500±50
Beta-42494	2599-179-50	C	8, West	49	104	510±60
Beta-42495	2599-224-57	B	5, South	42	17	1090±130
Beta-42496	2599-114-61	A	1, West	104	*	50±50
Beta-42497	2599-180-62	C	8, West	49	*	520±70
Beta-43152	2599-159-6	C	3, North	102	32	3890±70
Beta-43153	2599-103-12	A	2, South	72	4	270±80
Beta-43154	2599-104-13	A	2, South	72	13	490±70
Beta-43155	2599-106-14	A	2, North	111	28	560±60
Beta-43156	2599-111-18	A	2, bottom	72	n/a	220±70
Beta-43157	2599-209-26	B	4, *	22	*	810±80
Beta-43158	2599-178-49	C	8, East	49	62	920±110
Beta-42159	2599-220-53	B	5, bottom	42	n/a	4090±100
Beta-43160	2599-223-56	B	10, East	42-44	8	1420±130

*Precise provenience uncertain.

The stratigraphic record of Locality 36 has two components. One is the natural stratigraphy of the bedrock and overlying soil prior to quarrying, the salient features of which were outlined in the previous chapter. Intact, pre-quarrying stratigraphy is preserved only in areas not subjected to intensive prehistoric quarrying; within quarried areas, only fragments of this record survive. This chapter focuses on deposits created by quarrying and processing toolstone, among which are layers of displaced soil, lenses of flakes, angular tuff, and opalite debris, mixtures of silt and debitage in quarry pit fill, and layers containing burned toolstone and charcoal. On the profiles accompanying the text, quarry deposits dominated by fine matrix and silty soil cover are represented by gray shading; open framework clast-dominated lenses of flakes, angular tuff, and quarry debris are unshaded.

Ridge Top Area

The top of the ridge is overlain by 30 to 60 cm of silty soil over a red clay paleosol developed on soft tuff bedrock. The silts are largely eolian and evidence little or no internal stratigraphy. Nevertheless, radiocarbon assays obtained from hearths exposed by test excavations and grader scraping show a tendency to sort by depth below surface. Dates of 410+60 (BETA 42488), 330+50 (BETA 42487), 310+60 (BETA 42490) and 280+50 (BETA 42489) were obtained from hearths lying between 10 and 20 cm below surface, while near-surface hearth, Feature 110, returned a date of 150±70 (Beta 42491). Insufficient charcoal was obtained from Feature 108, another near-surface hearth.

As discussed in the previous chapter and in the description of Quarry Area A, below, eolian silts have accumulated on the ridge top and upper portion of the moderate slope. Because of this, not all extant quarry features at Locality 36 are currently visible on the surface. For instance, Feature 70, located about 10 m northeast of Feature 71 (Area A) was recorded originally as a surface lithic scatter. Test excavation revealed the scatter to consist of debris from the berm of a buried quarry pit brought to the surface by bioturbation. We must assume that other pits lurk beneath the surface of untested and unscraped areas of the ridge, particularly around its southeastern and eastern margins along the same contours as Areas A, B, and C.

Trench 6: Natural Soil Profile

Trench 6 provides an ideal view of the natural soil profile along the southwestern aspect slope. So culturally undisturbed a view of the natural stratigraphy allows better comparison with cultural deposits, facilitates recognition of cultural deposits by their unique characteristics exclusive of natural features, and reflects how natural processes at this locality may have modified cultural sediments.

Figure 56 depicts both the general details of the north wall of Trench 6, as well as four detailed, 1.0 meter wide, soil profiles selected along the exposure. Unit 1 is a brown, granular to sandy silt loam that makes up the typical surface soil in this area (Appendix D: Table 9). Below an abrupt contact with Unit 1, Unit 2 is a strongly structured, blocky to prismatic, red clay paleosol remnant common under many surface silts in the Tosawihi area. This clay rests on Unit 3, a kaolinitic weathered tuff bedrock which grades into unweathered rhyolitic tuffs below. Variation of this general profile along the trench illustrates the dynamic nature of the slope.

Soil thickness reflects slope dynamics and the nature of the underlying bedrock. Unit 3, the weathered bedrock, is of fairly uniform thickness over tuff but thins markedly over opalite (compare Profile B to Profile D). Clearly, natural weathering has penetrated deeper into the softer, more porous tuff. Opalite bedrock occurs at three locations in the trench: near the west end of the profile, between the 3.0 and 4.0 meter marks where it appears to be an isolated bed, and finally near the 23 meter mark and beyond to the end of the trench where it occurs more extensively (and where quarrying activity was more intense).

The Unit 2 clay soil is thinnest and most disturbed, or nonexistent, on top and upslope of opalite bedrock, and thickest, retaining its blocky to prismatic ped structure, just downslope of the opalite. The Unit 1 silts are also thickest just downslope of opalite bedrock.

These patterns suggest that erosion and slopewash had their greatest effects upslope of opalite, while deposition and perhaps slope stability was greatest just downhill. Although no detailed studies of ongoing natural slope processes have been attempted here, these patterns suggest that differences in water infiltration and resulting variations in slopewash intensity are constrained by the presence of porous versus non-porous bedrock and by changes in slope gradient due to bedrock variation. Soil creep is operating on this slope as well, evidenced by a downslope 'bending' of the upper portions of the prismatic peds in Unit 2.

Stratigraphy of Quarry Area A

Features 71 and 72 (Figure 57) are among the largest quarry pits at Locality 36; too, they are the deepest from the surface, with well developed berms. They lie on the eastern margin of a cluster of more shallow pits traversed by the dirt track through the site. Inadvertent blading of the track in 1989 leveled many of the pits in this group prior to mapping. Three backhoe trenches in Quarry Area A (1, 2, and 7) were excavated to explore the subsurface character of Features 71 and 72 (as well as the smaller Feature 73 that lay between them) and examine the deposits below the leveled road (cf. Figure 55; Figure 57). Trench 1, running northwest-southeast, cuts Features 71, 72, and 73. Trenches 2 and 7 are more or less perpendicular to Trench 1. Trench 2 bisects Feature 72 and extends southwest across the road. Trench 7 begins at the western margin of Trench 1 in Feature 71 and also extends across the road. These trenches expose silt-rich quarry deposits and provide an exceptional view of the bedrock topography resulting from quarrying in a Type 3 setting.

Figure 58 shows the east wall of Trench 1 as it cuts through Features 71 and 72. The uppermost layer of bedrock is up to 95 cm of chalky tuff. Overlying the tuff are patches of sandy clay paleosol up to 25 cm thick. This paleosol has a granular structure and apparently has experienced considerable reworking from bioturbation (rooting and faunal activity); silt fills krotovina between the paleosol and the tuff bedrock, and within the soft tuff itself. Overlying the tuff and paleosol is up to one meter of brown sandy silt loam. The profile also clearly shows that Features 71 and 72 were excavated through as much as 130 of silt, clay paleosol, and tuff bedrock to reach opalite. Quarry deposits consist of lithic debris from the quarrying of chalky tuff and thinly bedded to massive whitish gray opalite, often mixed with silt by bioturbation and infiltration.

Silt depth averages around 50 to 60 cm at the east end of Trench 2 (Figure 59), but is as much as 2.4 meters deep in pit-like structures in the chalky tuff bedrock created by sagebrush roots. Bedrock cavities created by roots at first were interpreted as "failed" quarry pits, abandoned before reaching toolstone. The rooted areas are distinguished from quarry pits, however, by silty fill lacking quarried lithic material, by their location in generally soft tuff bedrock, and by the presence of bedrock segments detached and uplifted from the main bedrock surface by roots. The fill of Feature 71, for example (cf. Figures 60 and 61), exhibits abundant weakly bedded lithic debris, and was excavated into hard opalite bedrock.

Similar stratigraphy is displayed in all the profiles of Quarry Area A. At the surface is an extensively bioturbated unit comprised of silt with opalite flakes and chunks. Below this lie sediments more easily recognizable as individual depositional units. Some are silt-rich, moderately bedded to poorly sorted or jumbled units with abundant chunks, flakes, and chips of opalite and tuff. Others are moderate to poor open frameworks of opalite chunks and flakes, or are hash-like, with a predominance of fine to medium opalite and tuff chips in a slightly clayey

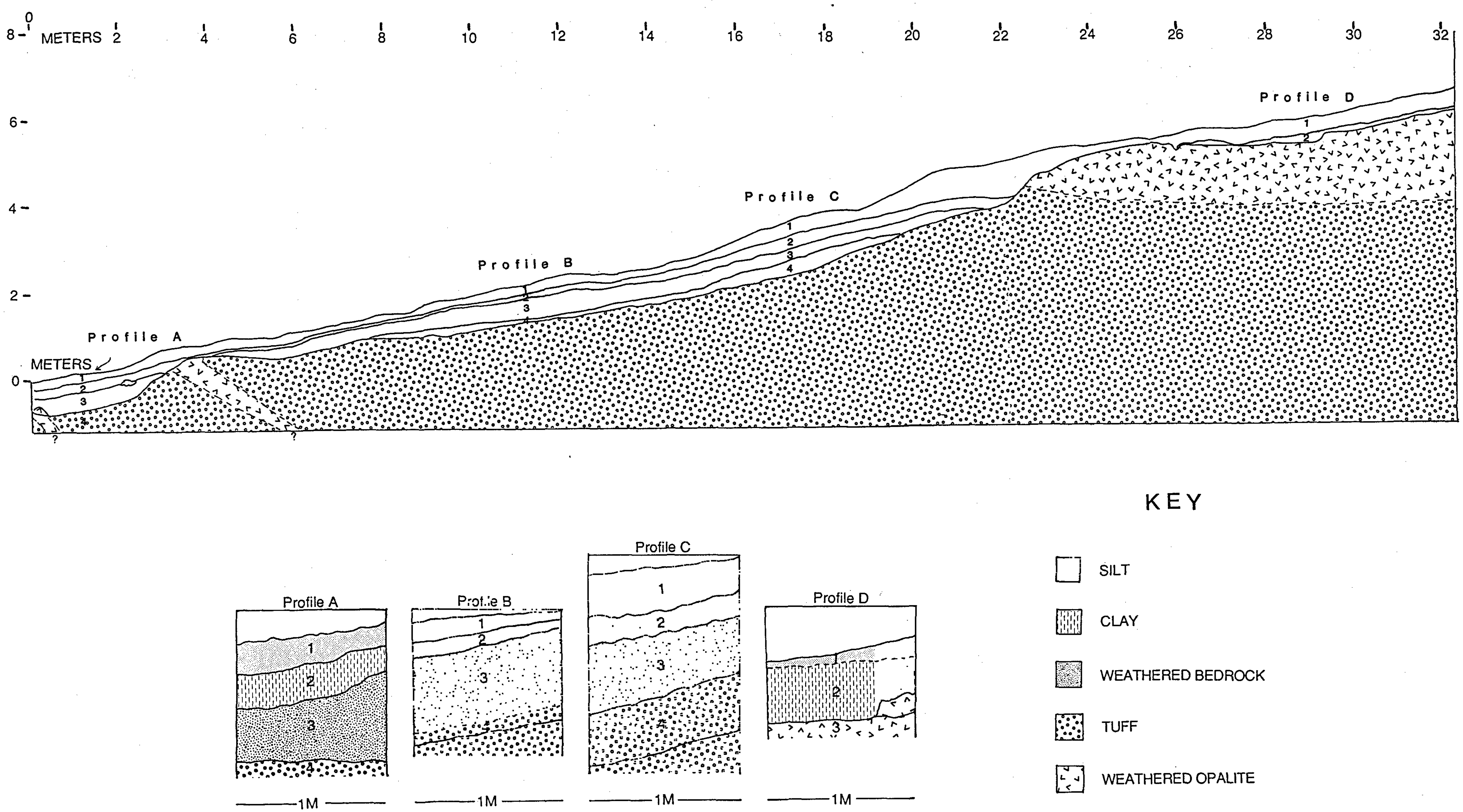


Figure 56. Trench 6, north wall profile, Area A.

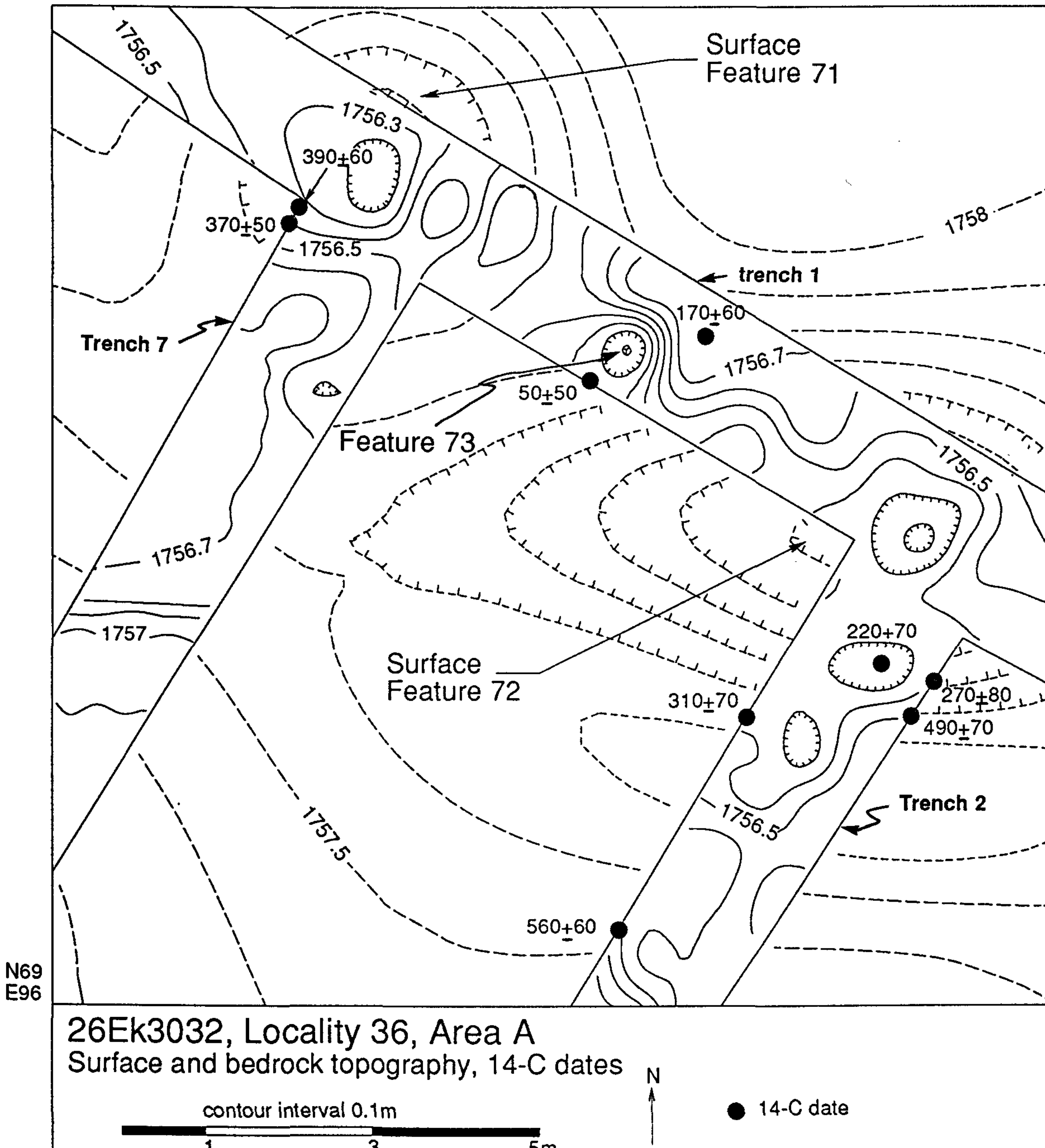


Figure 57. Surface and bedrock topography, Area A.

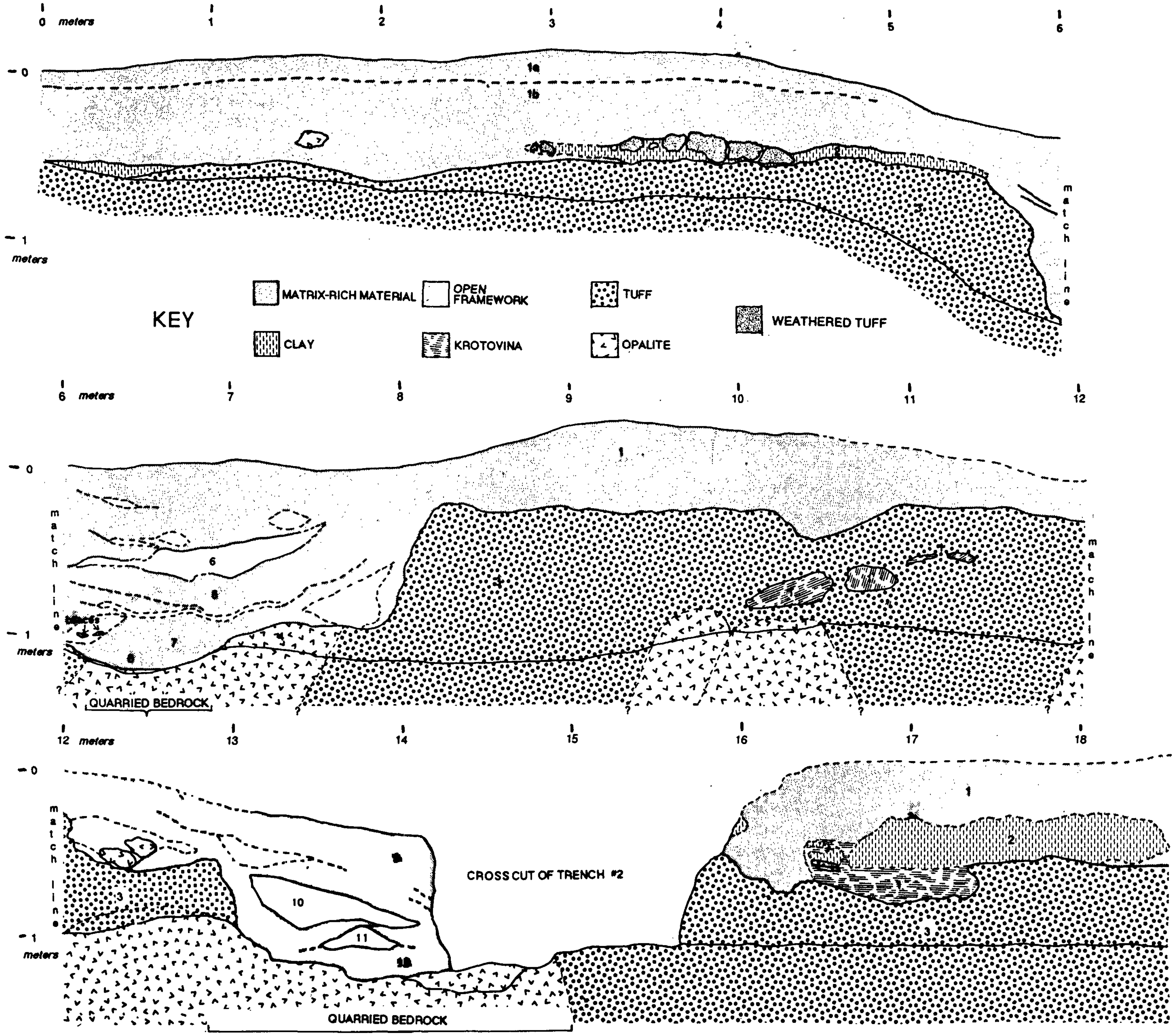


Figure 58. Trench 1, east wall profile, Area A

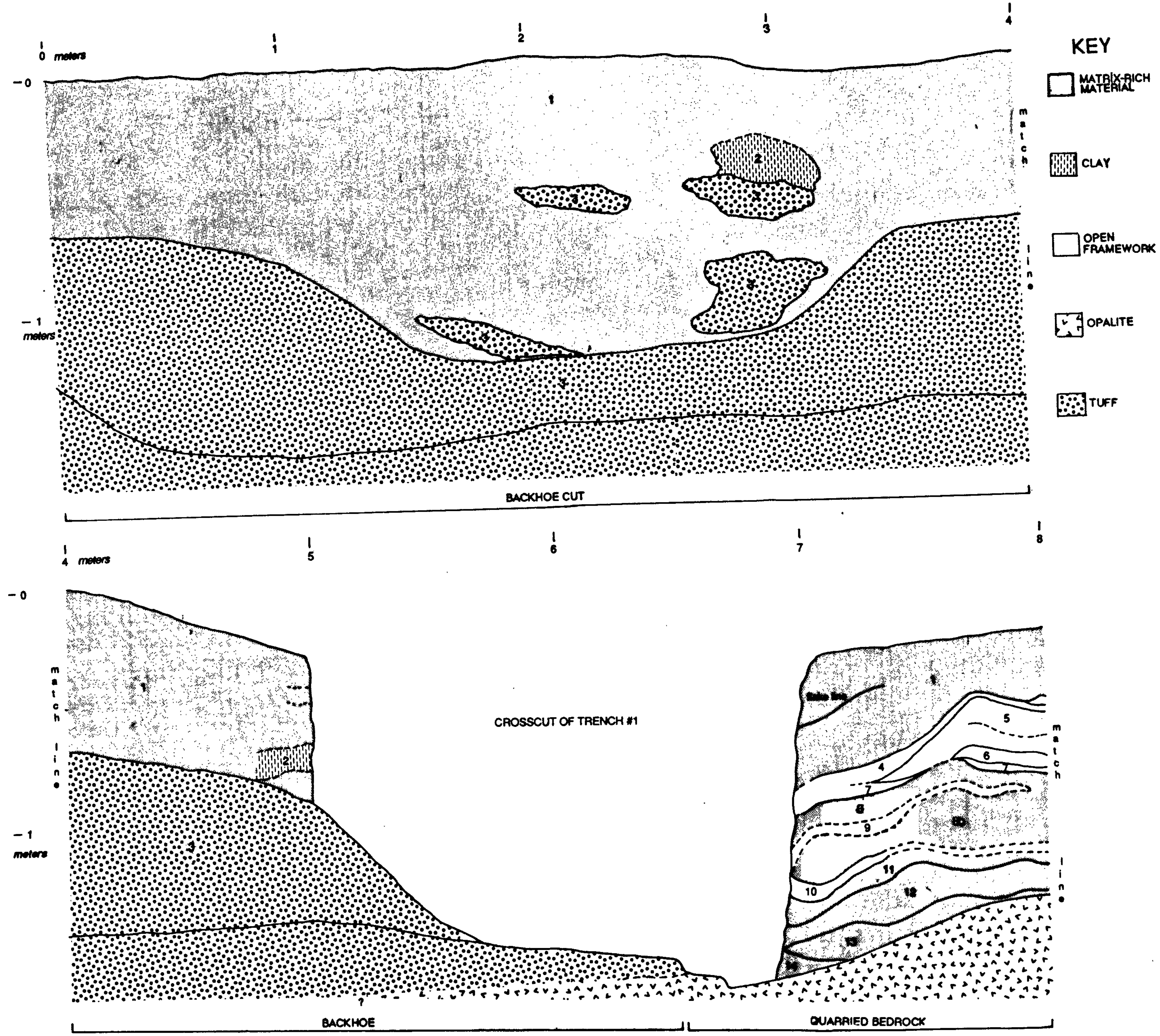


Figure 59. Trench 2, south wall profile, Area A.

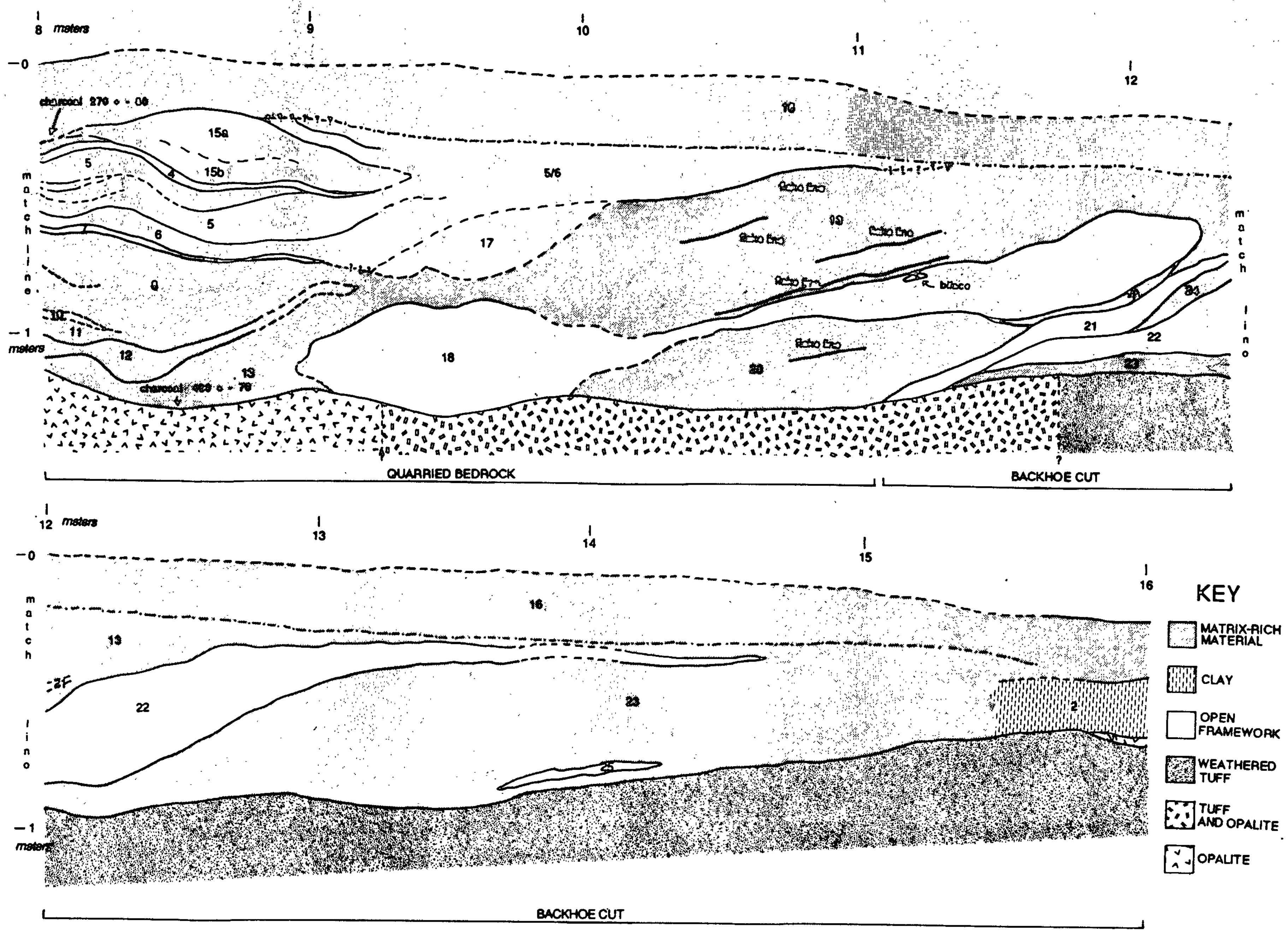


Figure 59, continued.

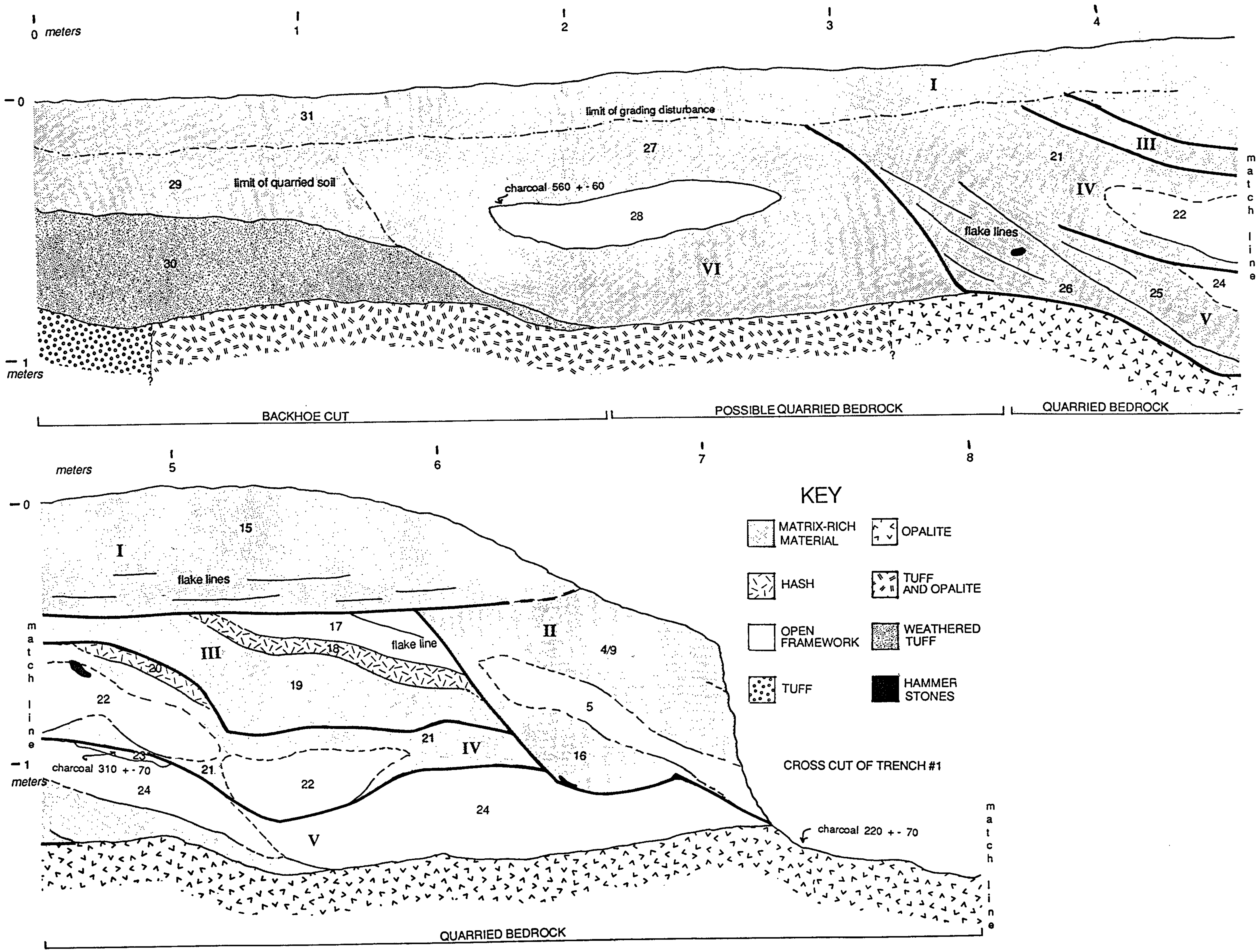


Figure 60. Trench 2, north wall profile, Area A.

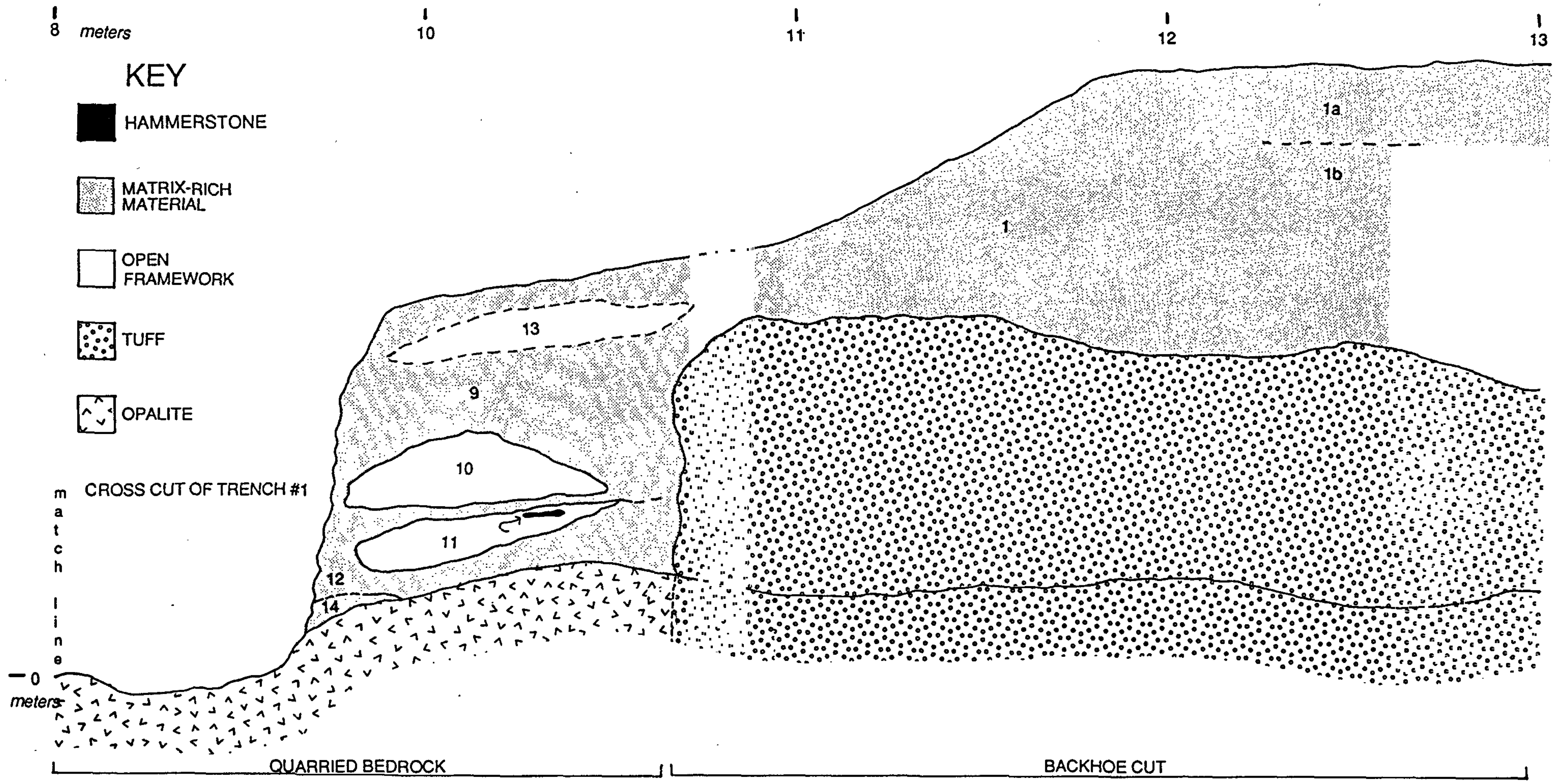


Figure 60, continued.

Figure 61. Silty quarry debris filling quarry pit in tuff, intersection of Trench 1, east wall and Trench 2, north wall, Area A (compare with Figure 60). Debris is resting on opalite; eastern pit margin is tuff.

sandy matrix. Nearest bedrock, units generally are well compacted with abundant hash-like matrix supporting opalite flakes and opalite and tuff chunks. Some slopewash units, such as Units 19 and 21 in the north wall of Trench 2, are present as well. Bone and antler artifacts (a *Bison* thoracic spine and a *Cervis* antler hammer/wedge) were recovered from coarse openwork deposits (Figure 62, Unit 17, west wall of Trench 1; Figure 63, Unit 12, south wall of Trench 7), where they probably were preserved by the inability of such sediments to retain water. Lenses of charcoal, found in all types of sediments, may represent fire setting as a quarrying technique, or may reflect warming hearths; all radiocarbon dates were obtained from such deposits.

Toolstone extraction in Quarry Area A appears to have been accomplished by digging down and laterally into the slope of the ridge to remove soil and tuff over opalite, then working downward into relatively small pits in the bedrock (cf. Figure 62), utilizing or creating joints and cracks in the opalite, isolating opalite segments by removing the surrounding tuff, or by following natural joints filled by more brittle secondary opalite. Since trenching revealed no adits in Quarry Area A, the presence of charcoal is perhaps less likely to represent fire setting, which seems to work best under an overhang or to weld tuff matrix. The increasing depth of soil and tuff overburden in an easterly direction is revealed most dramatically in the Trench 2 profiles (cf. Figures 59 and 60) and the east profile of Trench 1 (cf. Figure 59) that show the eastern margins of Features 71 and 72.

The presence of relatively intact clay paleosol over bedrock six meters (Trench 7) to 12 meters (Trench 2) west of Features 71 and 72 marks the western margins of quarrying in Quarry Area A. The morphology and orientation of strata suggests that quarrying started on the west, in the area now occupied by the road, where soil overlying bedrock was perhaps only 40 cm thick. The profiles of Trenches 2 and 7 (cf. Figures 59 and 60; Figures 63 and 64) through quarrying debris, clearly show the tendency of most strata to dip, and of most truncation surfaces to slope, down to the east, suggesting a succession of quarry pits and debris infilling eastward into the crest of the ridge.

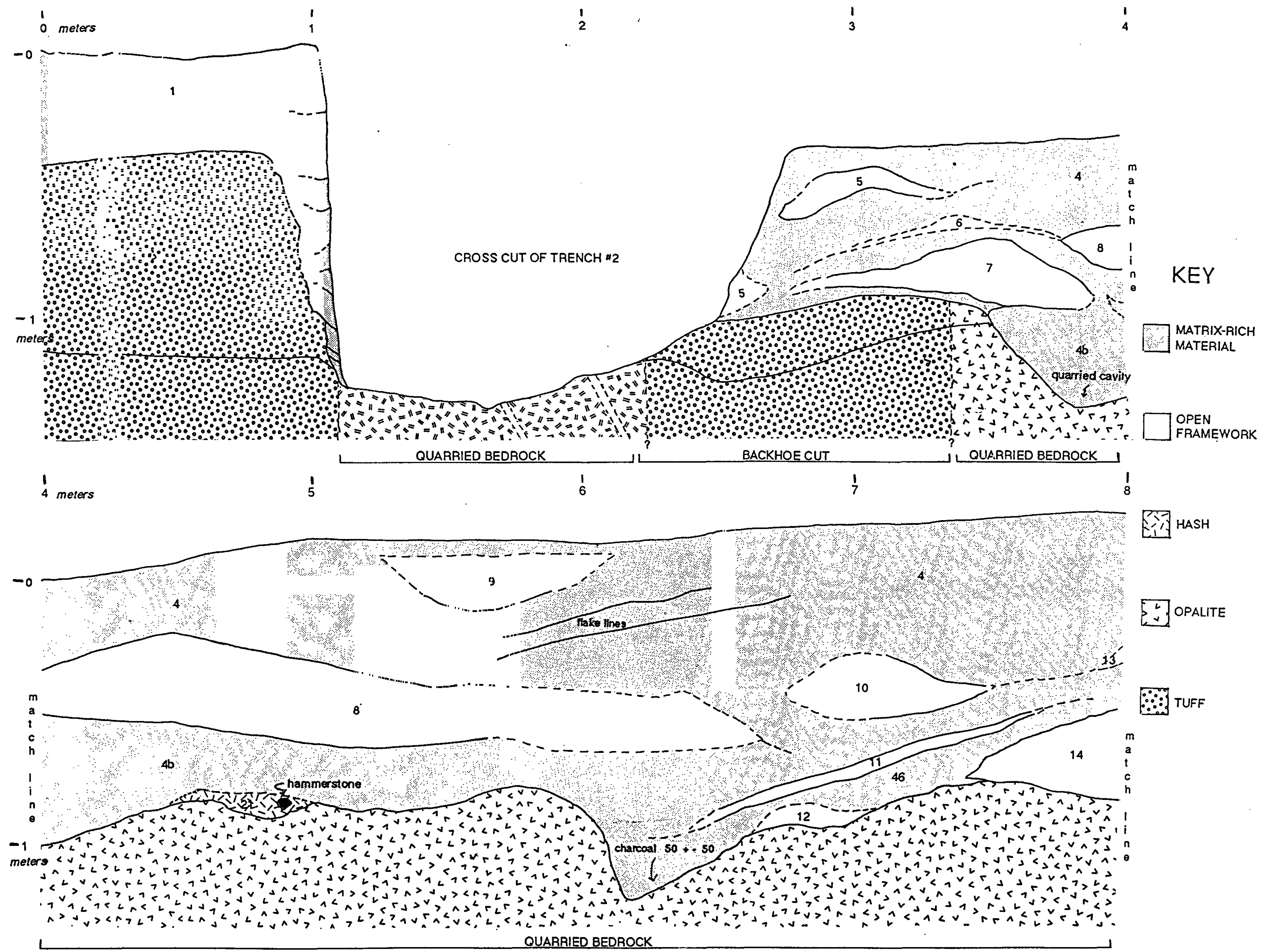


Figure 62. Trench 1, west wall profile, Area A.

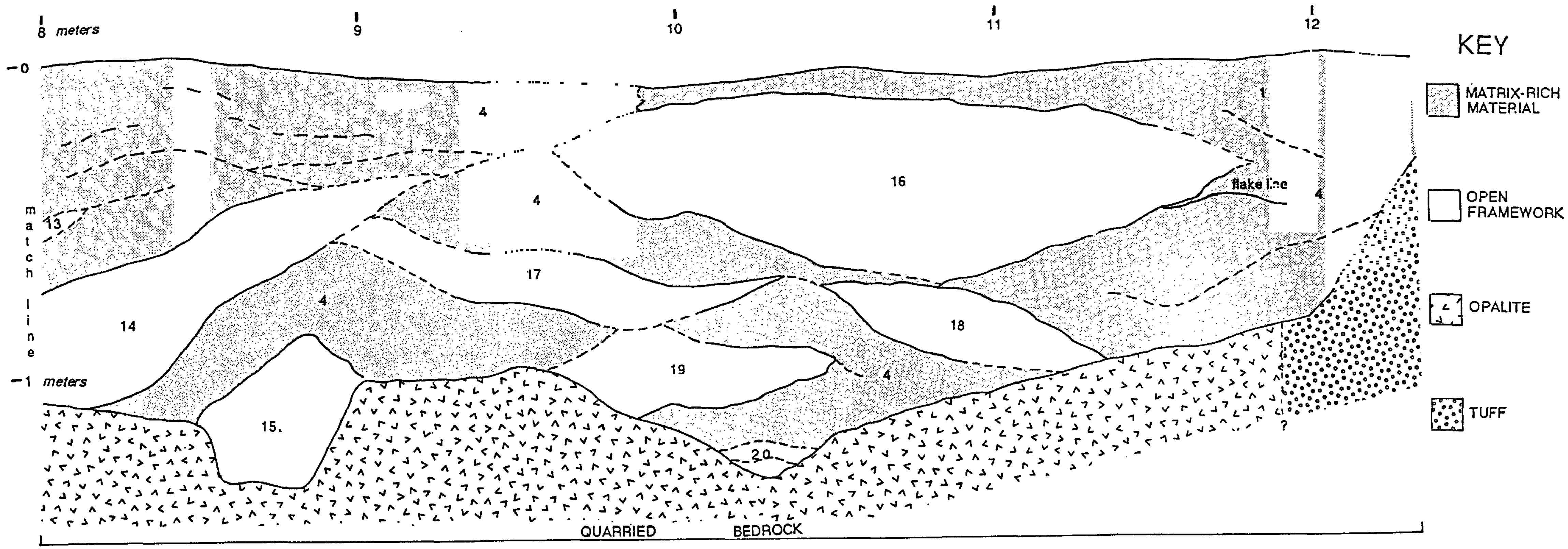


Figure 62, continued.

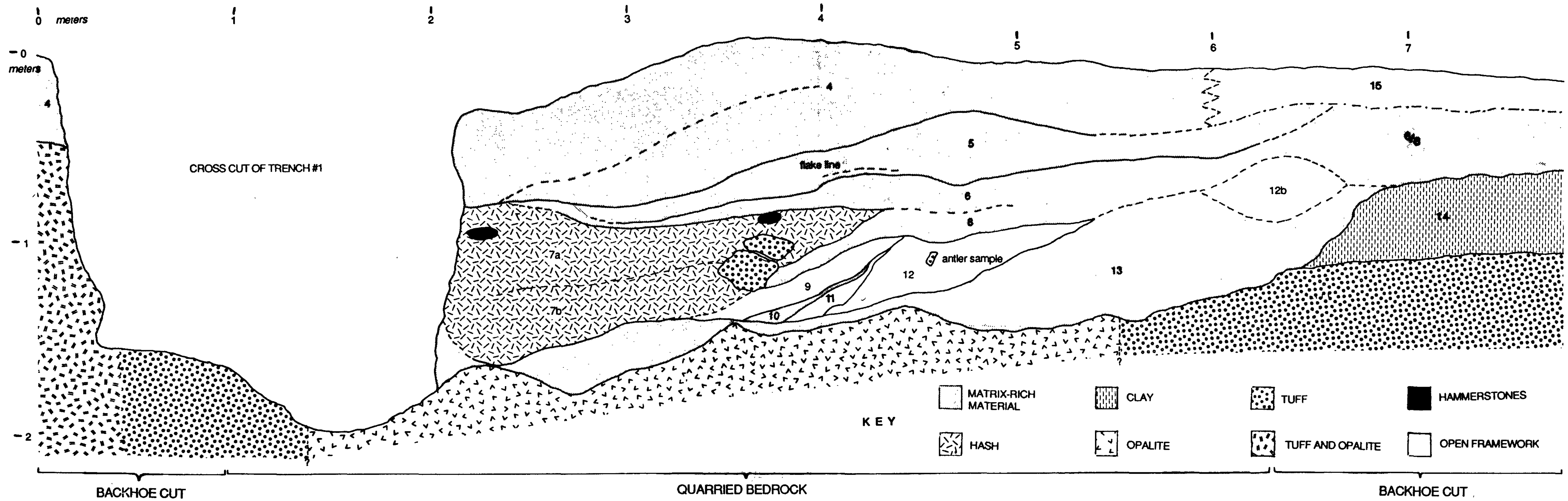


Figure 63. Trench 7, south wall profile, Area A.

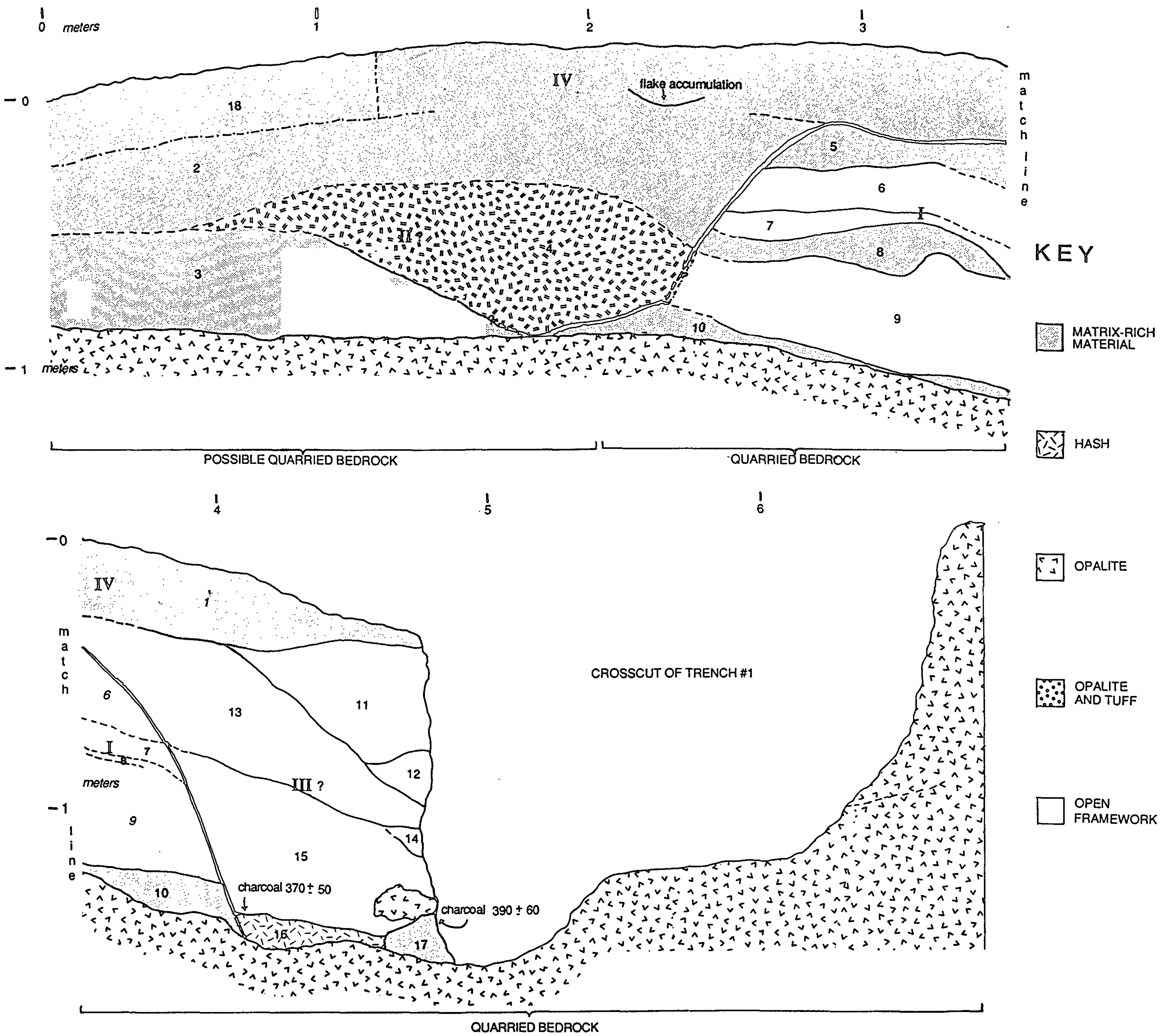


Figure 64. Trench 7, north wall profile, Area A.

Although the stratigraphy does suggest some lateral progression of quarrying perpendicular to the slope, there was a strong preference for quarrying eastward into the slope of the ridge. Indeed, this tendency probably accounts for the paucity of major stratigraphic breaks indicated by debris slumping, or truncation of earlier deposits, that makes it difficult to group Quarry Area A stratigraphic units into horizons. For instance, there are no obvious truncation surfaces in the south wall profile of Trench 2 (cf. Figure 59), and only one stratigraphic unit (Unit 12) is truncated in the south wall profile of Trench 7 (cf. Figure 63). In the north wall profile of Trench 7, however, at least six depositional horizons are apparent. Horizon I deposits (Units 5, 6, 7, 8, and 9) are truncated and overlain by Horizon II deposits (Units 11, 12, 13, 14, 15, 16, and 17) filling Feature 71, while Units 2 and 4 may represent a third horizon filling a pit west of Feature 71, not visible on the surface.

The most distinct series of horizons are seen in the north wall profile of Trench 2 (cf. Figure 60). A truncation surface cuts Units 30 and 29 of the pristine soil profile. Overlying this surface, the oldest cultural deposits, Units 28 and 27, comprise Horizon VI, dated by radiocarbon to 560±60 B.P. (BETA 43155). Horizon VI, in turn, is cut by a truncation surface and overlain by Units 26, 25, 24, and 23 (the latter, a charcoal lens) of Horizon V. The radiocarbon assay of charcoal from Unit 23 produced a date of 310±70 (BETA 42477). Units 20, 21, 22, and 24 comprise Horizon IV. The boundary between Horizons IV and V is relatively indistinct and based more on the steeper dip of Horizon V strata (compared to those in Horizon IV) than to actual truncation of Horizon V units. Horizon III contains Units 19, 18, and 17. Unit 19 truncates Units 20 and 21; weak soil-like development in Unit 19 may be due to incorporation of silty sediment developed during the break in deposition which occurred between the deposition of Units 21 and 19. Horizon II Units 16, 5, and 4/9 comprise the last fill of Feature 72. These overlay a truncation surface created by re-excavation of Feature 72 that cuts Units 17, 18, and 19 of Horizon III and Units 21 and 24 of Horizon V (Figure 60). Unit 16 of Horizon II was partly composed of debris slumped from Units 17, 18, and 19. Finally, Units 17, 18, and 19 of Horizon III and Units 16 and 4/9 of Horizon II in turn were truncated along their upper surfaces and overlain by Unit 15, comprising Horizon I.

The tendency toward eastward expansion of quarrying in Quarry Area A is further supported by radiocarbon dates that, in Trench 2, are progressively younger to the east: 560±60 B.P. to 310±70 B.P. (BETA 42477) on the north wall, 490±70 B.P. (BETA 43154) to 270±80 B.P. (BETA 42153) on the south wall, and 220±70 B.P. (BETA 42156) on the trench floor near its east end. At the east end of Trench 7 in the north wall (cf. Figure 64), dates from Units 15 and 17 of 370±50 B.P. (BETA 42478) and 390±60 B.P. (BETA 42480), respectively, are similar to dates from Trench 2 in an analogous stratigraphic position. Although this suggests that quarrying may have shifted ten meters laterally over one hundred years or so, or that the exposed working quarry face was at least ten meters wide (the distance between Trenches 2 and 7) at one time, the following evidence suggests a third alternative.

Radiocarbon dates of 50±50 B.P. (BETA 42496; Trench 1 bottom, Feature 104) and 170±60 B.P. (BETA 42479; Trench 2 bottom, Feature 104) from the surface of the bedrock between Features 71 and 72 are the youngest obtained from Locality 36 and indicate late bouts of quarrying. They are overlain, however, by material from the berms of Features 71 and 72, so both features must, therefore, be even younger. The youth of these features is suggested further by the depth of the open pits and the well defined berms surrounding them; erosion and deposition have not been long at work on them. Surface morphology suggests that Feature 72 is the younger, and this is supported somewhat by the stratigraphy of the east wall profile of Trench 1 (cf. Figure 59) where strata tend to dip southerly. Perhaps, then, the strategy in Quarry Area A was to work in two pits simultaneously; either could be expanded toward the other in case of a good toolstone strike, thus decreasing search time.

Stratigraphy of Quarry Area B

Quarry Area B is located on the upper reaches of the moderate, southwest-facing slope below the ridgecrest (cf. Figure 55); it was sampled by Trenches, 4, 5, 10, and 11 (Figure 65). The upper silt unit is thinner than in Area A, but the red clay paleosol is thicker where it has not been disturbed by quarrying. Quarrying has scoured the bedrock in Area B deeply, particularly in the vicinity of Trenches 5 and 10. The depth of deposits overlying bedrock therefore increases from 50 cm at the north end of Trench 4 to 180 cm at the south end of Trench 10. Although a Type 3 quarry setting (bedrock parallel to the ground surface) may have underlain the northeastern portion of Area B, a Type 2 setting (slope intersecting bedrock) seems likely for most of the area. In any case, quarrying sooner or later transformed nearly all of Area B into a Type 2 setting.

The slope of strata exposed in the south wall profile of Trench 11 (Figure 66) suggests that quarriers tended to work progressively into the slope here as they did in Area A. An adit excavated into the soft tuff below a layer of opalite about 25 cm thick is located at the north end of Trench 11 where it is intersected by Trench 4 (cf. Figures 65 and 66). A line parallel to the upper slope of the opalite layer intersects the surface about 5.5 m west of the adit and about 1.5 meters east of the point the slope begins to become steep. This suggests that the opalite layer once lay in a Type 2 situation at or near the surface at the break in slope, and has been worked back to its present position. The alignment of pits to the south indicates this strategy prevailed over several meters along the lateral extent of the same opalite bed.

The west wall profile of Trench 4 clearly displays the thickening of sediments over bedrock toward the south (Figure 67). At the extreme north end of the trench, the soil is typical of the Tosawihi area (Figure 68); essentially undisturbed by quarrying, it is comprised of 20 to 40 cm of brown to gray silt with an abrupt lower contact over 20 to 40 cm of reddish clay paleosol possessing well developed structure with blocky to prismatic peds overlying tuff and opalite bedrock. The vertical peds and the tendency for bedrock clasts to be detached and transported upward into the overlying soil through shrinking and swelling of the clay are well illustrated in Figure 68. In addition to natural bedrock casts, the clay often contains some quarry debris (tuff or opalite chunks, or opalite debitage) incorporated, either by bioturbation or by partial disturbance and mixing from quarrying. Further south along Trench 4, disturbance of the natural soil profile becomes more intense. The number of individual stratigraphic units increases along with the amount of quarry debris they contain. Although little or nothing remains of the clay paleosol, the clay and silt content of the matrix in Area B remains high.

Trench 4 was cut through an intersecting series of small pits visible on the surface that suggested alignment along the edge of a bedrock feature (running roughly northwest to southeast). Signs of quarrying are evident in the bedrock of the trench bottom as small pits, battered working surfaces, and minor adits, producing a scoured bedrock surface (Figure 69).

Trench 5 intersects the extreme southern end of Trench 4, cutting thick, lithic-rich quarry deposits overlying massive, whitish-gray opalite exposed near the east end (Figures 70 and 71). Extensive bedrock quarrying has resulted in a stepped exposure of opalite and tuff, sloping up to the east. The upper step is approximately 0.8 meters high, forming a face of nearly pure massive opalite. Figure 70 shows the small adit driven into the foot of the bedrock step that is not apparent in the south wall profile of Trench 5 (cf. Figure 71). An exposure of bedrock similar to that exposed in Trench 5 also includes a small adit at the south end of Trench 10 (Figure 72), suggesting that both are part of the same quarried face (now buried by debris to the east) and possibly extending as well to the north and south of the two trenches.

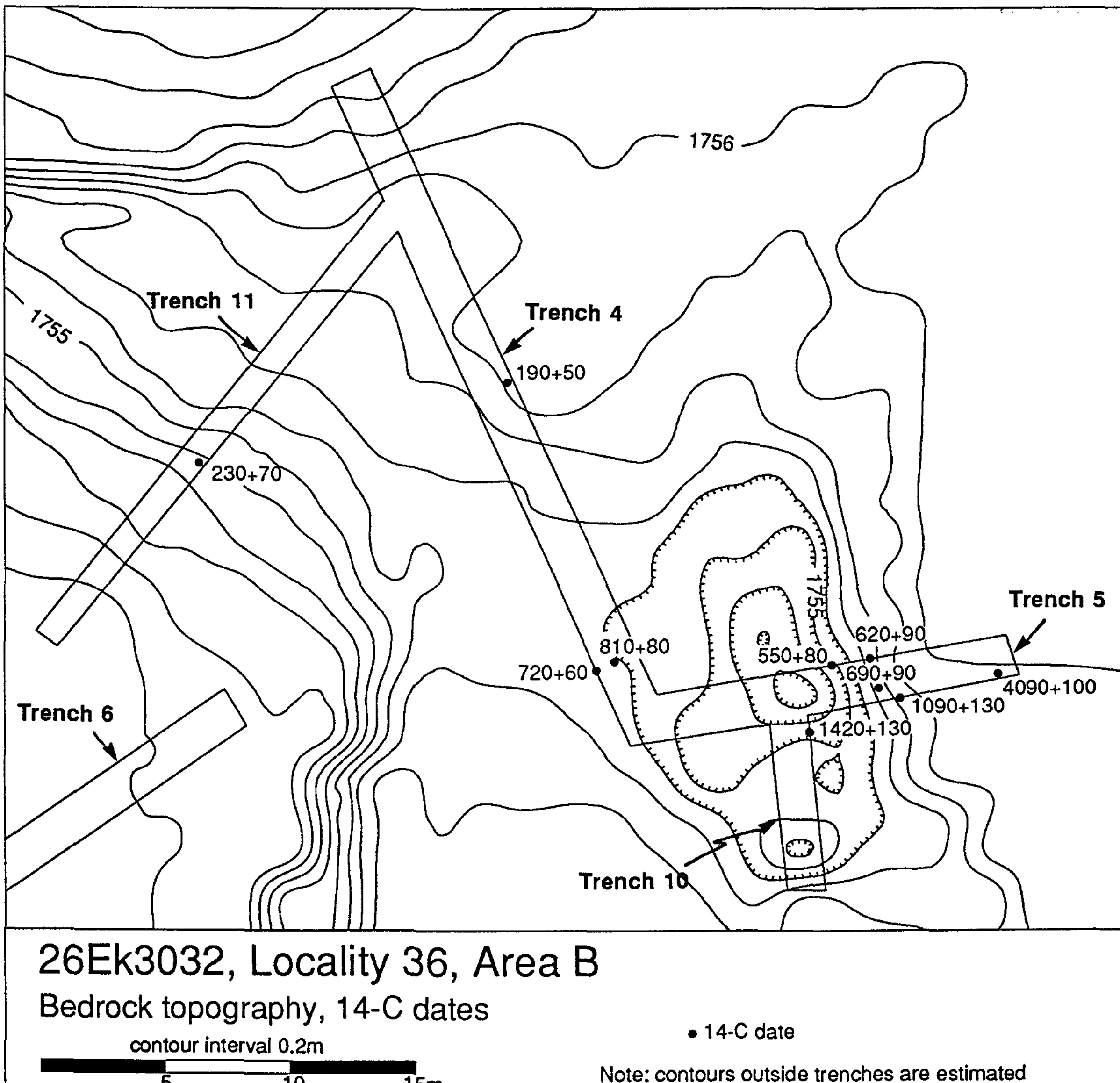


Figure 65. Surface and bedrock topography, Area B.

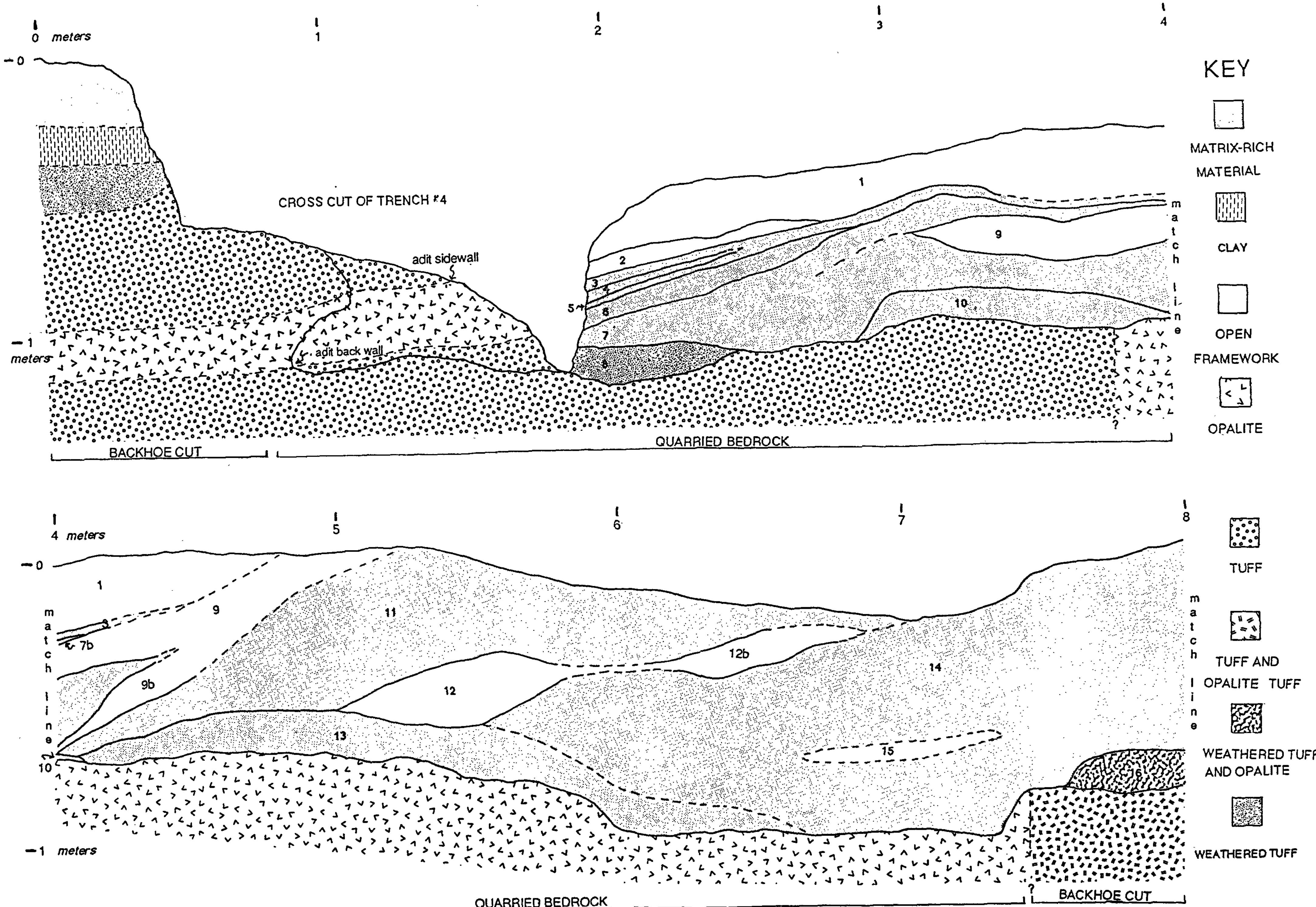
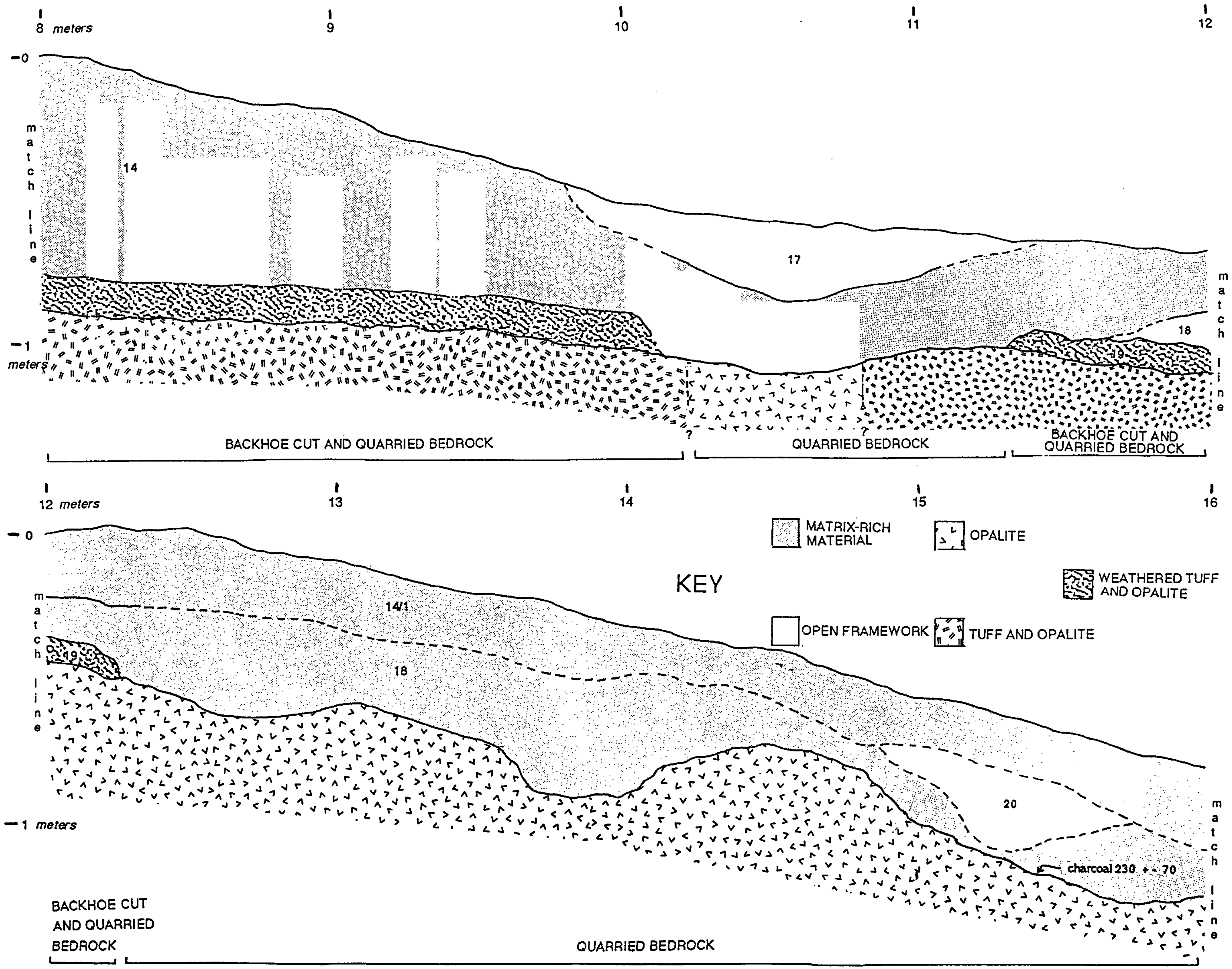


Figure 66. Trench 11, south wall profile.



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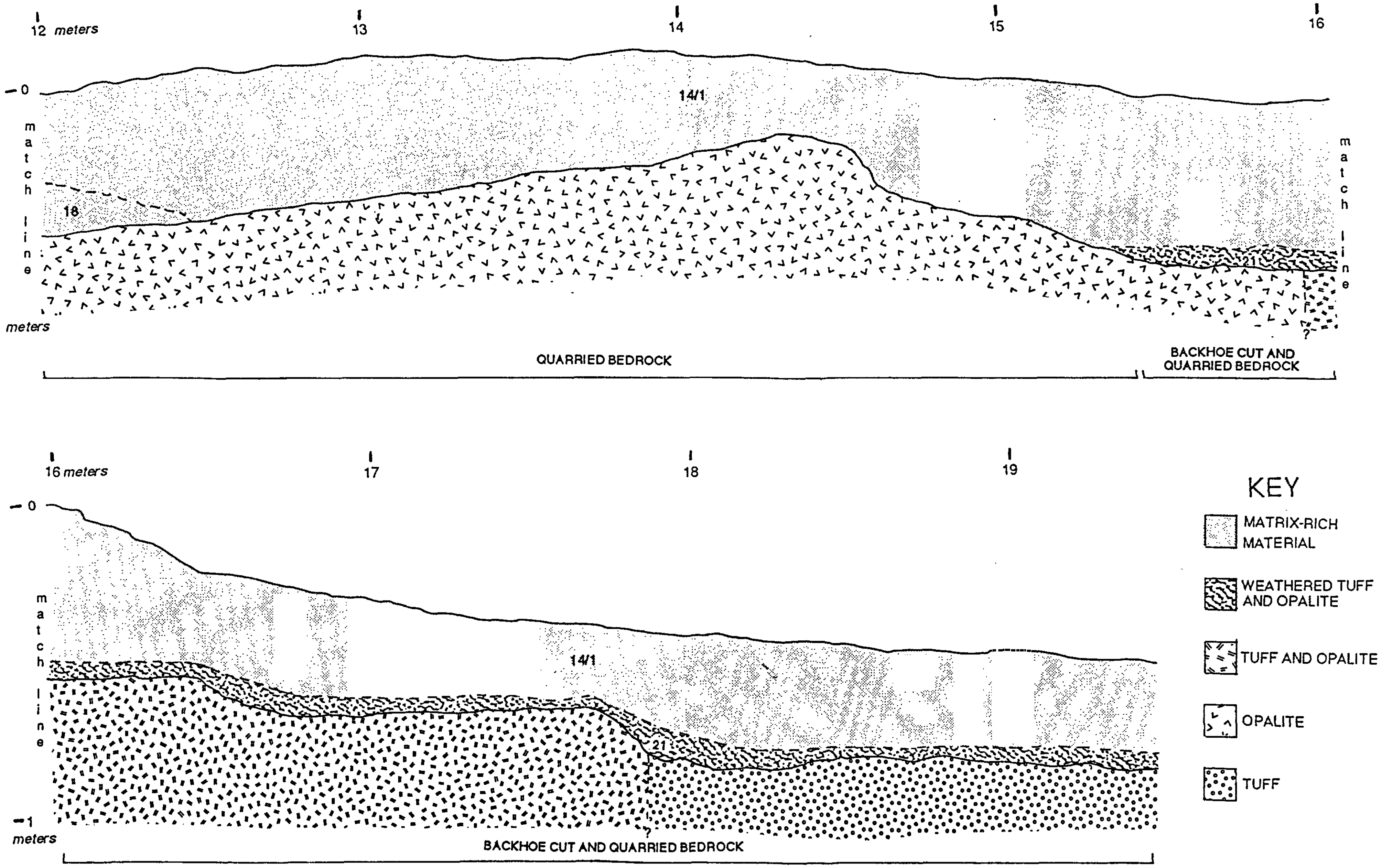


Figure 66, continued.

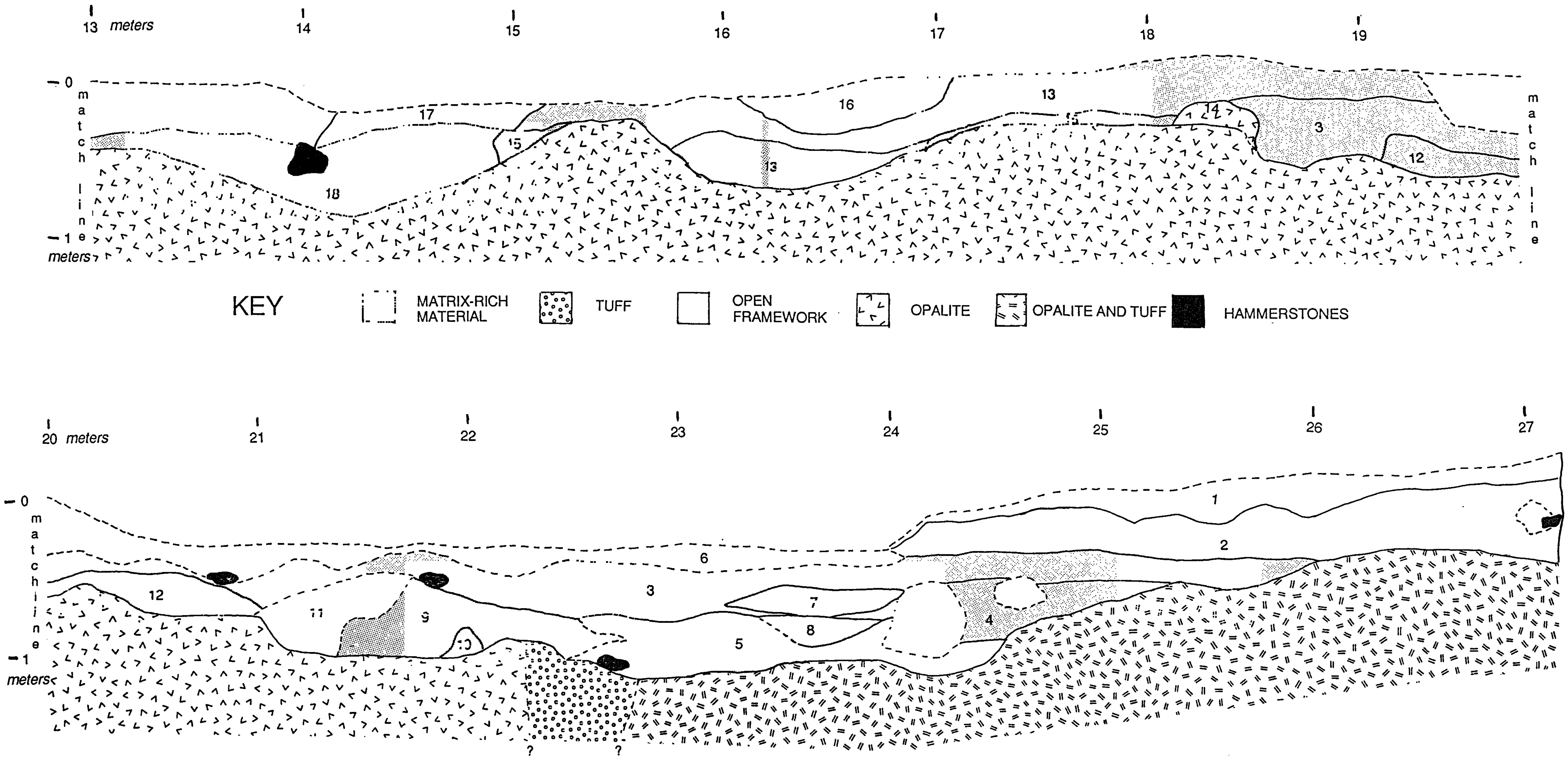


Figure 67. Trench 4, west wall profile, Area B.

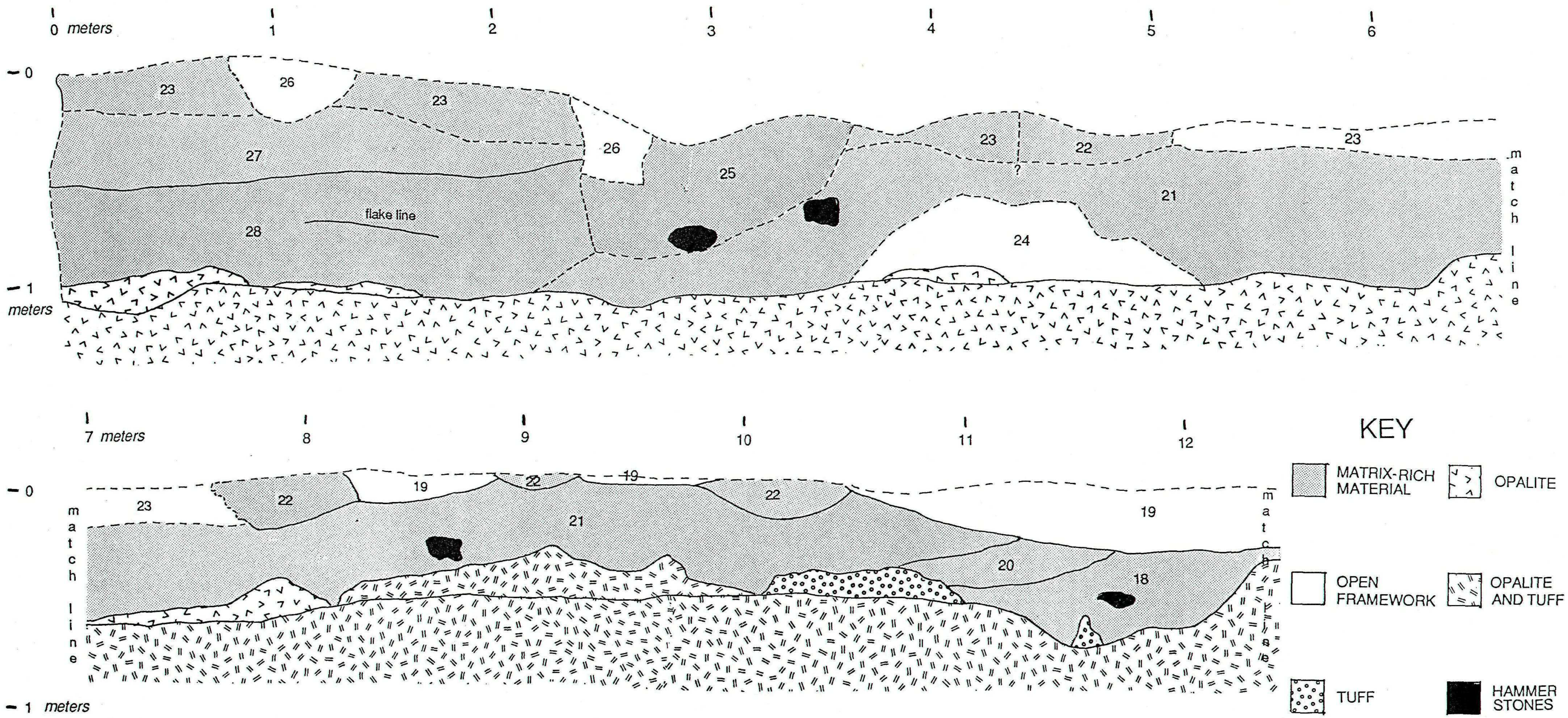


Figure 67, continued.

Figure 68. Weathered opalite bedrock and intact clay paleosol, Trench 4, north end of east wall.

The debris deposits of Trenches 5 and 10 were created by quarrying the massive face described above, with the result that all are dominated by opalite flakes and chunks with fewer tuff clasts than observed in Area A deposits (Appendix D: Tables 8 and 13). Area B deposits become more matrix-rich and more clay-rich towards the west end of Trench 5 where they are similar to the deposits encountered in Trench 4.

The exposed strata in Trenches 5 (cf. Figure 71) and 10 (cf. Figure 72) suggest a complex history in this portion of Area B, with multiple cycles of excavation, quarrying, waste disposal, pit filling, and re-excavation. The deposits of Trench 10 are similar to those of Trench 5, although somewhat richer in clay and silt. The more clay-rich character of the deposits exposed in Trench 10 and the lack of clear definition of a quarry feature at the surface suggests that the oldest deposits in Quarry Area B lie here. This is supported somewhat by radiocarbon dates, as discussed below.

The south wall profile of Trench 5 (cf. Figure 71), although interrupted by its intersection with Trench 10, shows that two pits were excavated into the bedrock floor. The east wall of Trench 10 (cf. Figure 72) intersects the east wall of the largest pit, ca. three meters wide at this point, with a flat bottom. A smaller pit, 1.8 meters wide with a more irregular bottom, occurs about 1.5 meters to the east; its eastern margin forms the high "step" in the profile mentioned previously (cf. Figure 70). Deposits here evidence abrupt, nearly vertical truncations of some strata, such as Units 6 and 7 by Unit 9, or Units 14 and 15 by Units 11 and 12. Other strata appear almost split, such as Unit 27 where it meets Unit 7. This configuration may owe to the slumping of the upper portion over the younger adjacent unit; more likely, there is an unrecognized stratigraphic break.

Although it is possible to group some strata into horizons, stratigraphic complexity is so great that it is difficult to order horizons in a meaningful way. For example, a stack of sediments (Units 52, 48, 46, 45, 40, 39, 38, 33, 31, 31a, 29, 28) that is convex upwards, represents the buried

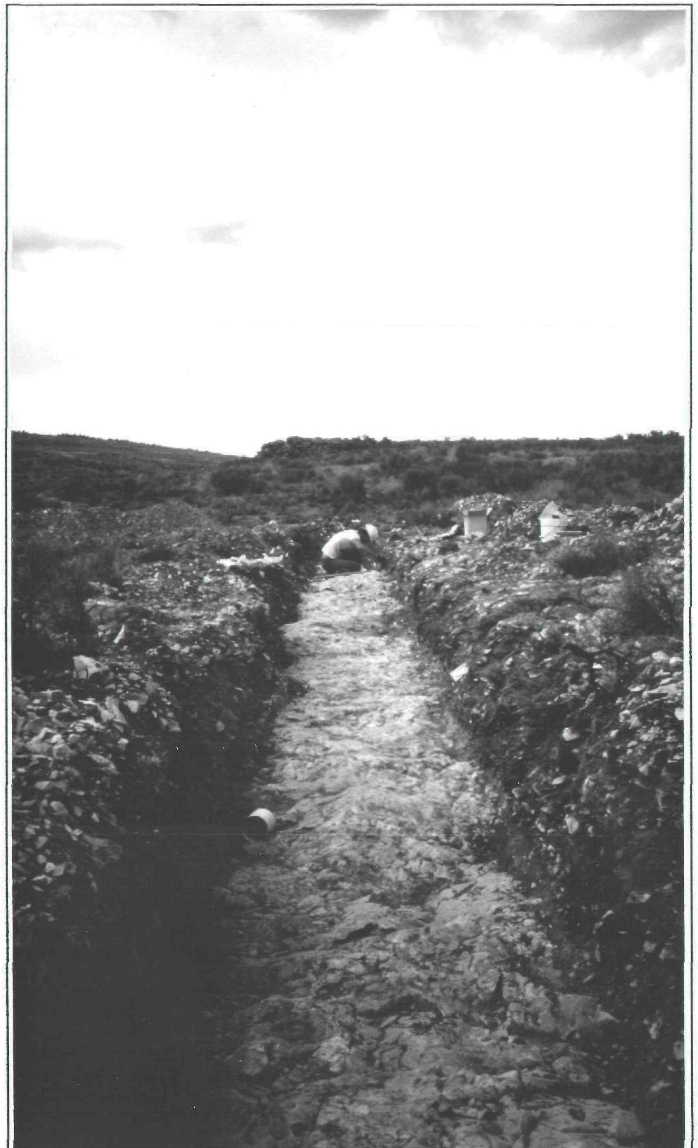


Figure 69. Scoured opalite bedrock floor exposed in bottom of Trench 4, Area B (looking north). Note the increasing depth of overburden toward the viewer (south).

Figure 70. Stepped opalite bedrock floor exposed in bottom of Trench 5, Area B (looking east). East wall of large bedrock quarry pit with small adit below menu board (compare with Figure 71).

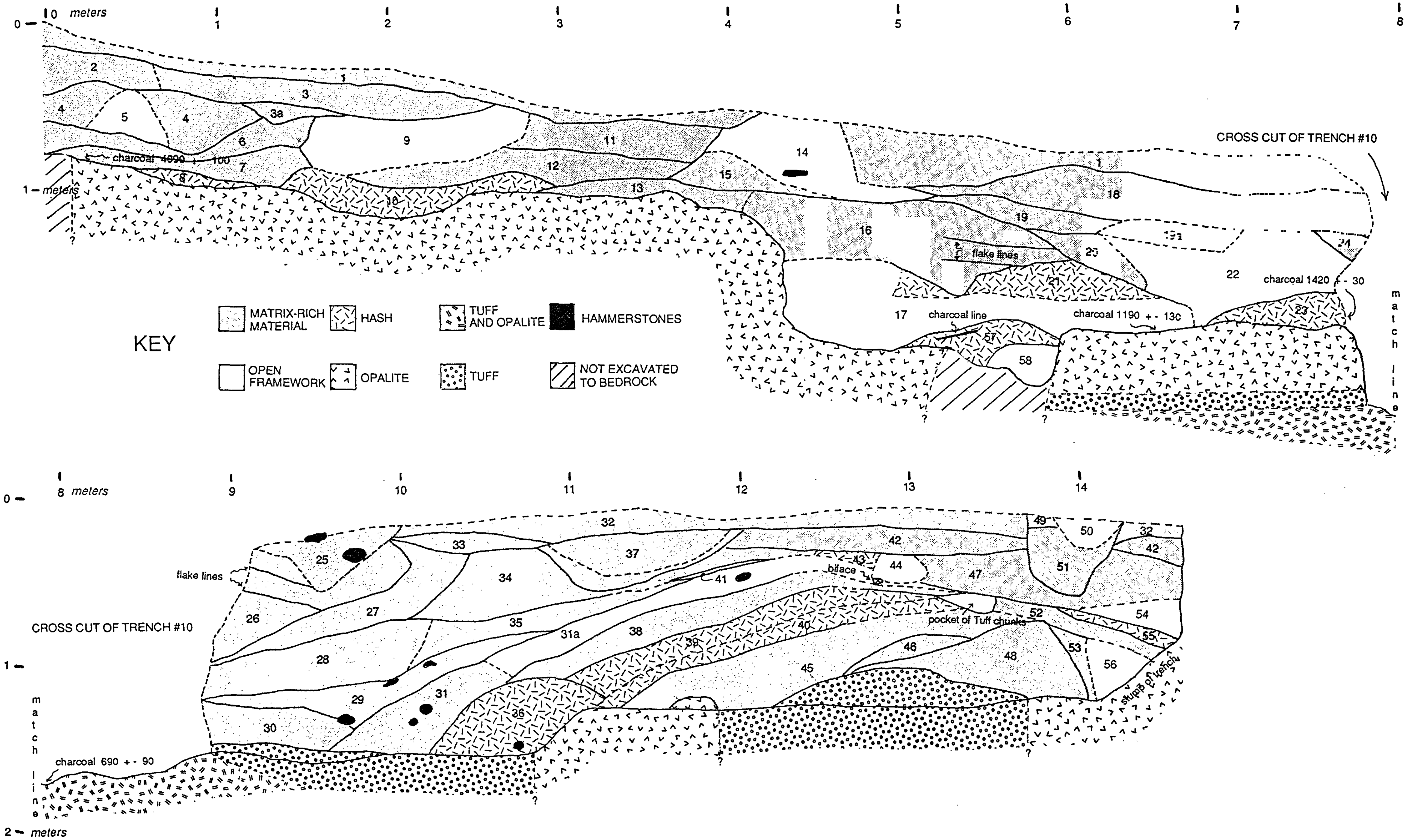


Figure 71. Trench 5, south wall profile, Area B.

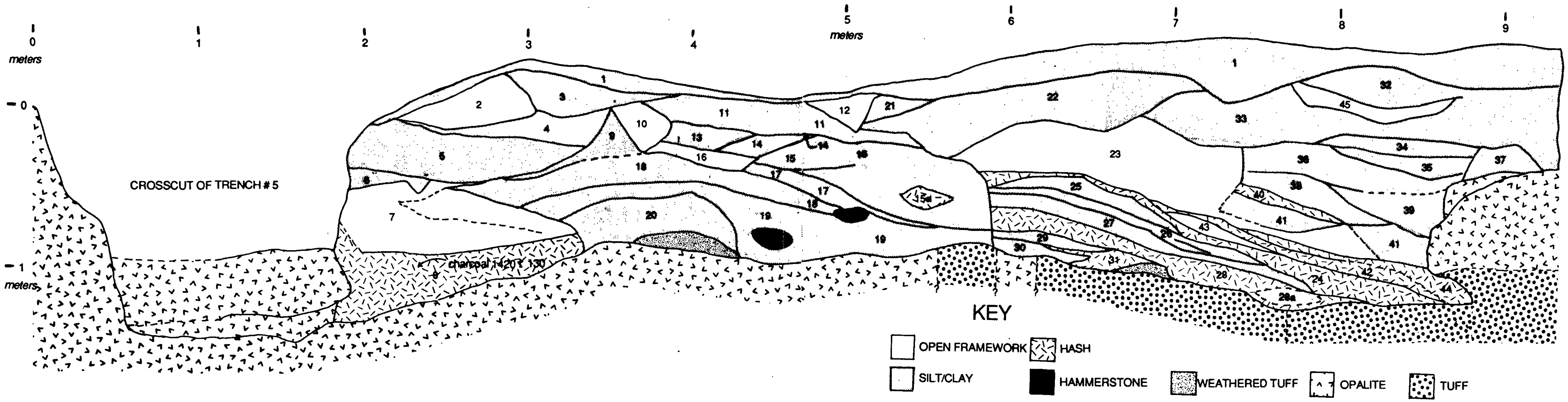


Figure 72. Trench 10, east wall profile, Area B.

berm of quarried debris excavated from the largest bedrock pit in the floor of Trench 5. This pit was subsequently filled with deposits (Units 30, 29, 28, 34) resting on its bedrock floor. A date of 690±130 (BETA 42486) was obtained from charcoal at the bottom of this pit, at the base of Trench 5. Another group of sediments (Units 61, 60, 17, 16, 15) are stacked into the easternmost bedrock pit. A radiocarbon date of 1090±130 (BETA 42495) was obtained from charcoal at the bottom of Unit 17, resting on bedrock between the larger and smaller pits; Unit 23 also rests on the same bedrock surface. Just around the corner of the intersection of Trenches 5 and 10, in the east wall of Trench 10 (cf. Figure 72), Unit 23 fills a small bedrock pit. Charcoal from the Unit 23 exposure was dated at 1420±130 (BETA 43160), making this the oldest dated pit-filling deposit. Nevertheless, the orientation of strata suggests that the excavation of the adit in the southern end of Trench 10, and its subsequent filling, occurred after the deposition of Unit 23.

Unit 8, a charcoal rich lens of hash resting on bedrock near the eastern end of Trench 5 (cf. Figure 71), contained charcoal, but not enough was collected for radiocarbon assay. Another charcoal sample was recovered from bedrock just 30 cm north of Unit 8 in the bottom of Trench 5. While we cannot be certain that this sample also represents Unit 8, it is likely that it does. In any case, the sample yielded the oldest radiocarbon (4090±100 B.P., BETA 42159) date from Locality 36. So old a date was unexpected; the shallow deposits overlying Unit 8 are divided into intercalated, truncated units suggesting no particular order or great antiquity.

The upper ten to twenty centimeters of deposits along Trench 5 consist of units more or less parallel to the present surface. They are, however, discontinuous, broken here and there by small pit excavations such as those filled by Units 37, 50 and 51 (cf. Figure 71).

While radiocarbon dates suggest a tendency for deposits in Area B to be younger toward the northeast (cf. Figure 65), stratigraphic relationships are less ordered, and suggest a less systematic quarrying strategy. This is particularly true in the vicinity of Trenches 5 and 10, where massive opalite bedrock seems to have offered a tempting target that was attacked whenever possible with adits, probably working back and forth along the quarried face. Re-excavation of old quarry waste was frequent, even though quarrying experiments have shown it to be a costly strategy. The concentration on lithic resources offered in the southern portion of Area B resulted in the large, scoured depression at the intersection of Trenches 5 and 10, the stepped bedrock slope to the east, and the welter of truncated and intersecting strata observed in the profiles.

Stratigraphy of Quarry Area C

The several quarry pits (Features 18, 47, 48, 49, and 50) of Quarry Area C are aligned roughly along the lower reaches of the moderate slope (cf. Figure 55). Area C was sampled by Trenches, 3, 8, and 9 (Figure 73). Trench 8 was cut through Features 48 and 49, perpendicular to the slope (Figure 74). Trench 3 was excavated parallel to the slope, beginning at the upper (eastern) margin of Feature 49, extending about 20 meters westward to cross Trench 8 and thence through the break between the moderate and steep slope (Figure 75). In order to expose the buried quarry feature discovered in the western portion of Trench 3 more fully, Trench 3 Extension was opened from the western end of Trench 3 in a 4.5 meter dogleg to the northwest, thence westward 30 meters down the slope; only the dog leg portion of the extension was profiled (cf. Figure 75). Trench 9 extends a few meters eastward from the Trench 8, but was very shallow and revealed nothing of stratigraphic interest, although it did help delineate the shape of the bedrock.

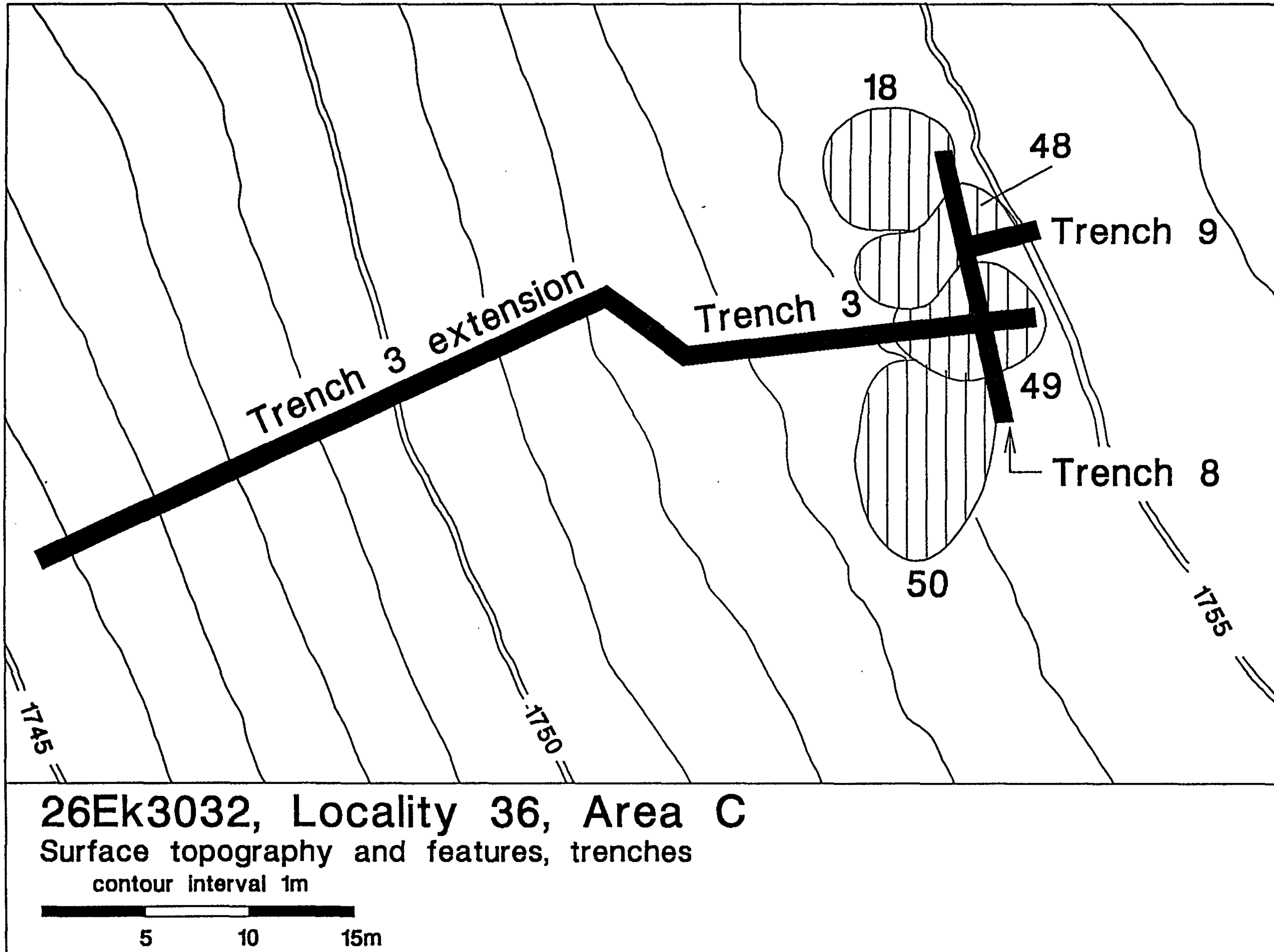


Figure 73. Surface and bedrock topography, Area C.

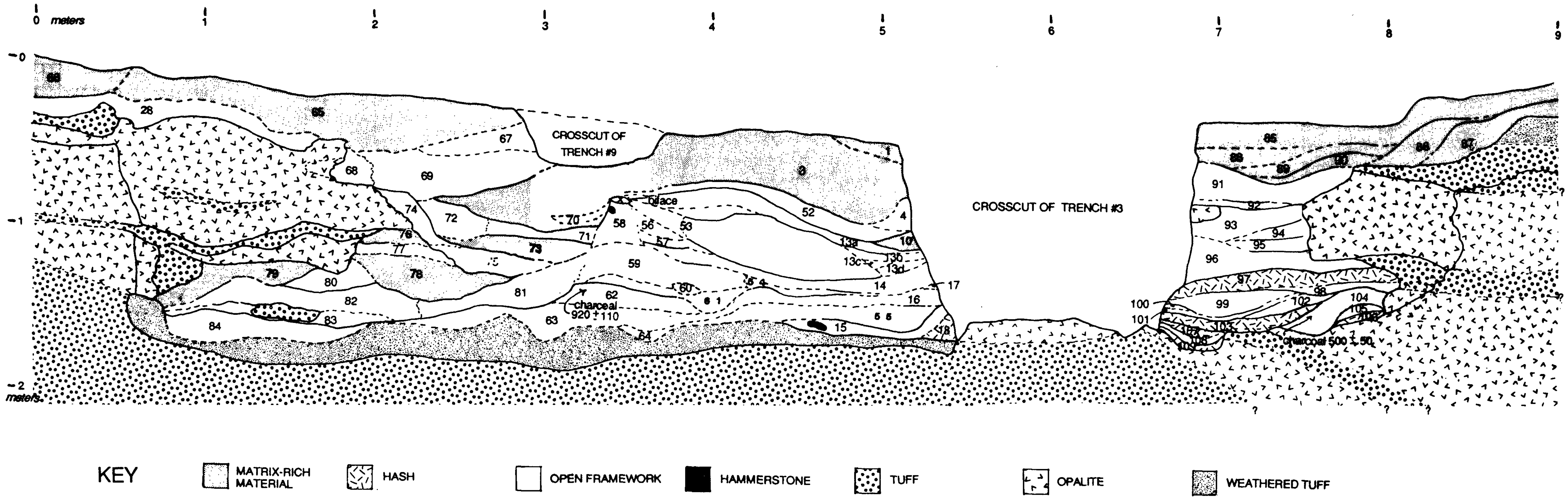


Figure 74. Trench 8, east wall profile, Area C.

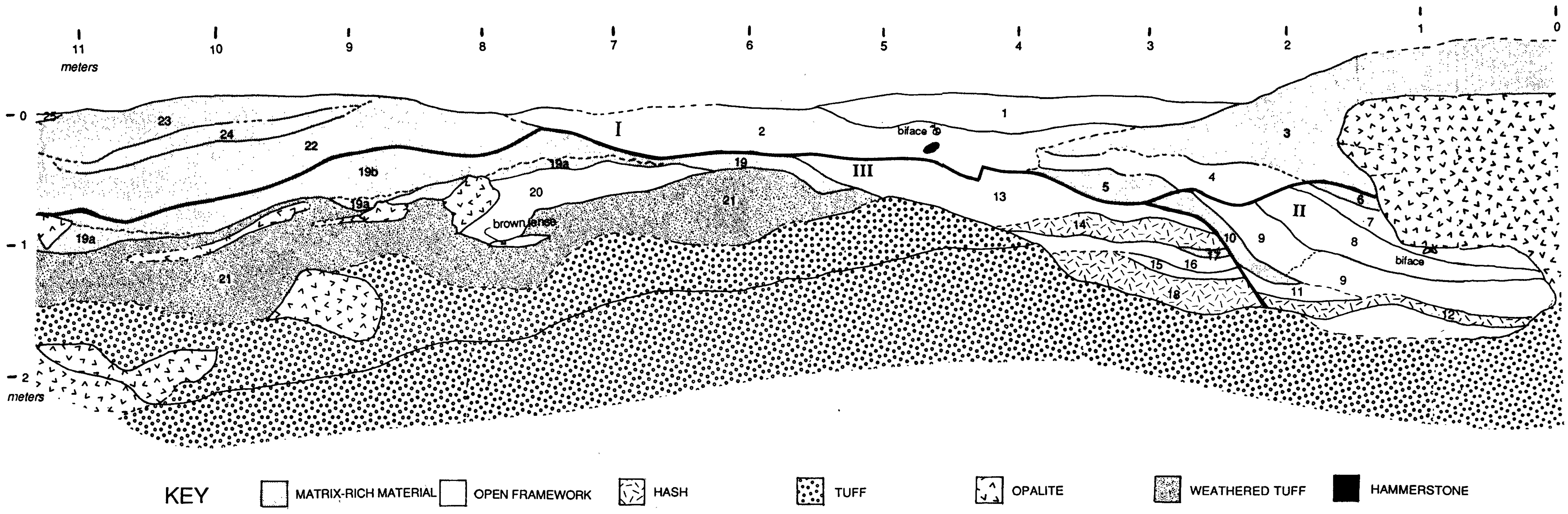


Figure 75. Trench 3 and Trench 3 extension, north and west wall profiles, Area C.

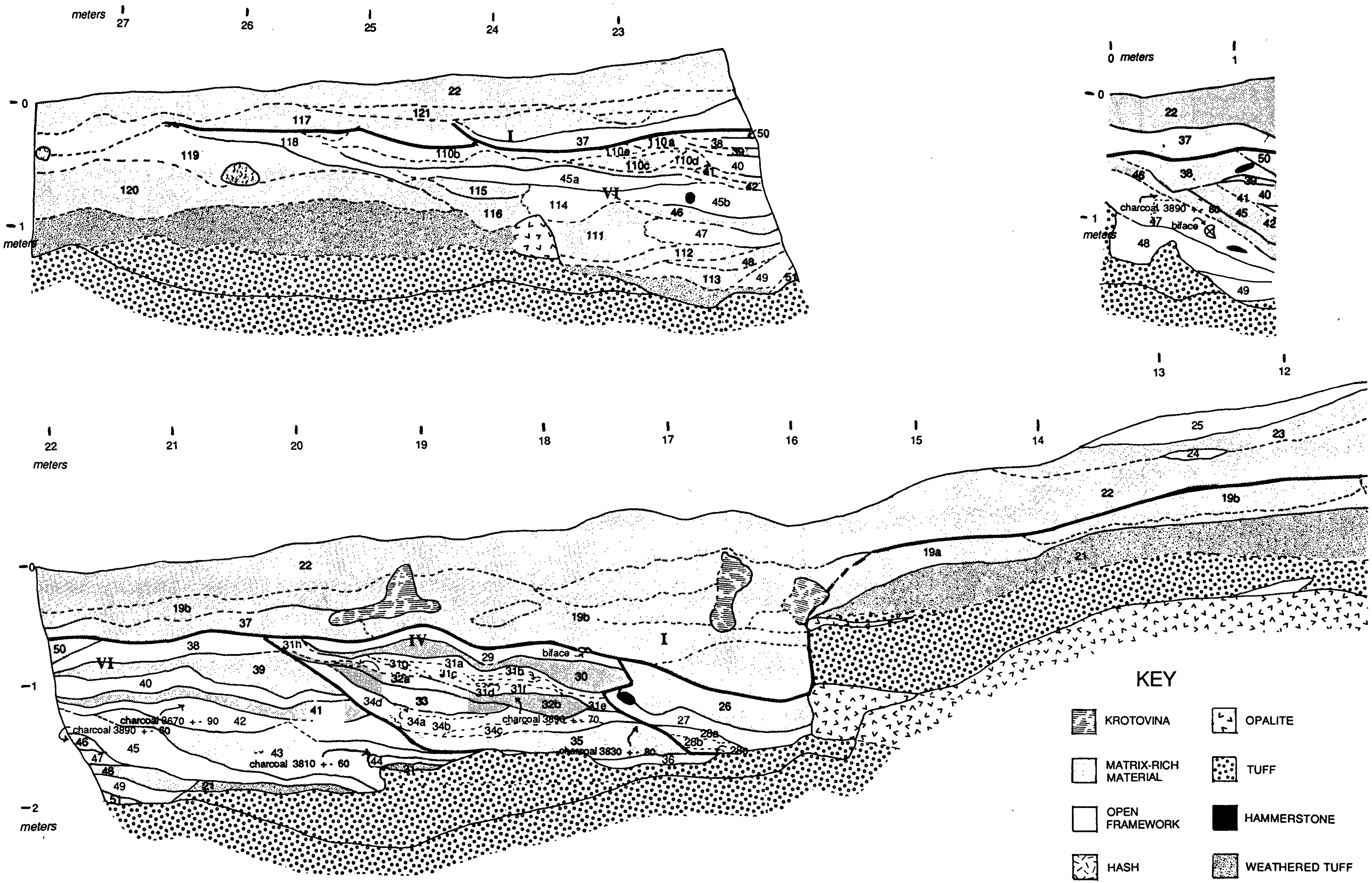


Figure 75, continued.

Bedrock Morphology and Stratigraphy

Bedrock morphology and stratigraphy in Area C is well exposed and quarrying strategies are revealed clearly. Trenching demonstrated that surface quarry pits are aligned along a bedrock face perpendicular to the slope. In Feature 49, quarrying by excavation of adits created an arcuate embayment (convex up-slope) about six meters wide, moving the bedrock face two or three meters eastward. The northern and southern edges of this feature are marked by bedrock exposed in Trench 8 (cf. Figure 74). Another arcuate embayment in the bedrock face to the north of Feature 49 is suggested by Features 48 and 47.

The bedrock face undermined by the adit in Feature 49 is apparently the lower edge of the opalite cap forming the ridge top, dipping down to the east. At the eastern end of north wall profile of Trench 3 (cf. Figure 75), the bedrock is comprised of alternating beds of opalite and tuff. The uppermost layer, 25 cm thick, is a vuggy, fractured, white to translucent opalite with patches of red and pink. Very little of this material was processed into tools. Beneath this lies 15 cm of tuff, below which is another bed of white opalite about 80 cm thick resting on tuff. This bed is the toolstone sought by the prehistoric quarries who created Feature 49. The adit visible in the eastern end of Trench 3 (cf. Figure 75, Figures 76 and 77) is presently one meter deep and one meter high at the entrance, narrowing to 40 cm high at its terminus, and would have required the quarrier to lie prone while working. It was apparently driven along a fracture zone (possibly a bedding plane) running through the middle of the opalite bed, removing the upper and lower tuffs to detach material from the roof as well as from the floor; roof material is of higher quality than that of the floor. The tabular basalt wedges found in Feature 49 debris (but nowhere else on the site; cf. Chapter 6) seem well suited for working the cracked opalite and soft tuff found here.

The tuff underlying the opalite of Feature 49 is at least 2 meters thick, containing lenses and large, boulder-sized nodular inclusions of white opalite with thin, swirling gray bands that is high quality toolstone. Between about 2.5 meters and 11 meters west of the present bedrock face, the tuff is overlain by 30 cm of sandy silty colluvium containing abundant opalite quarry debris and flakes. The upper 20 to 40 cm of the tuff is strongly weathered into angular fragments with clay skins. A pocket in the upper surface of tuff filled with clay (Unit 20) is probably a relict patch of the paleosol observed elsewhere on the site. This weathering profile is old, and, where it is intact, no quarrying ever has taken place.

Eleven meters west of the Feature 49 adit, the weathered tuff is truncated by the east wall of Feature 102, a quarry pit completely buried by the colluvial blanket and not visible on the surface. Feature 102 intersects a bed of high quality, swirling banded opalite about 30 cm thick that dips to the east (cf. Figure 73 and Figure 78); it rests on tuff of undetermined thickness. A line extending the upper surface of the opalite bed to the west intersects the present surface at the western edge of the Feature 102 pit, observed in the north wall profile of Trench 3 Extension (cf. Figure 75). The lateral extent of Feature 102 is unknown. The tuff enclosing the opalite bed exploited in Feature 102 is soft, suggesting that opalite could have been isolated easily and large chunks detached by percussion or fire setting. This situation seems ideal for the production of flake blanks, either struck from large detached pieces or directly from the isolated bedrock.

The Trench 3 Extension profile also shows a decrease in the slope of the present surface and the surface of the lowest tuff unit, west of Feature 102. The pre-quarrying weathering profile is similar to that observed between Features 49 and 102, where the upper 20 to 30 cm of tuff is highly weathered and overlain with a clay paleosol.

Figure 76. Quarry debris filling adit at eastern end of Trench 3, Area C (looking north, northeast). Tag at top of photo is 3.5 cm wide.

Figure 77. Cleaned adit, eastern end of Trench 3, Area C (looking east). Menu board just north of intersection of Trench 8 and Trench 3.

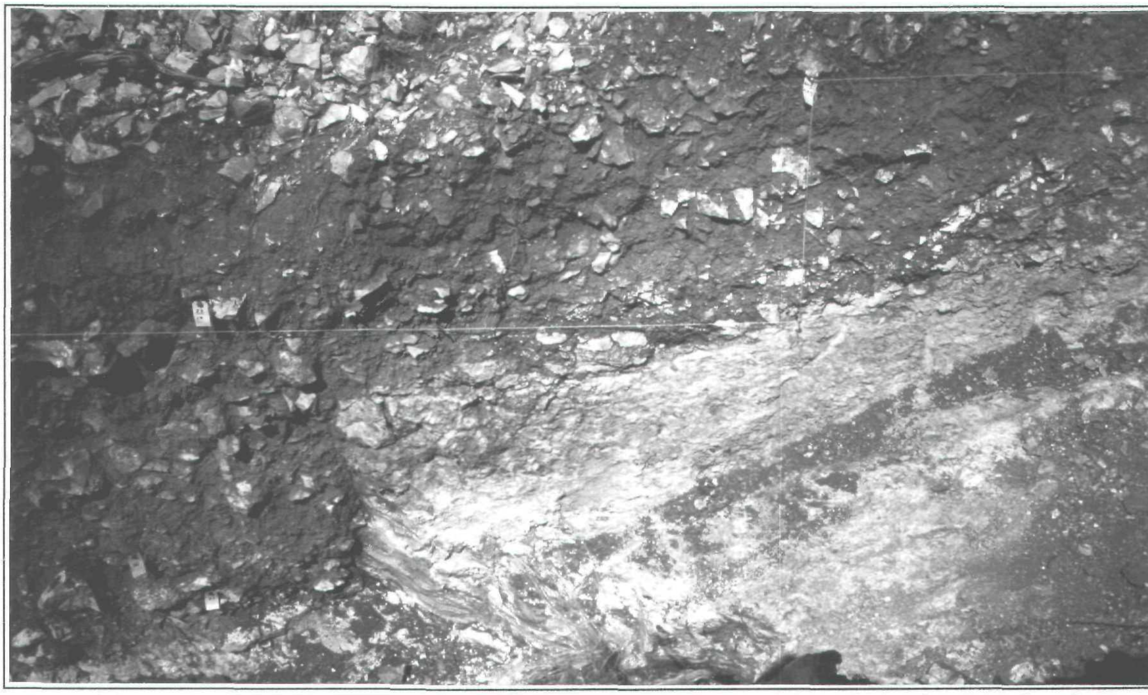


Figure 78. Quarry face at eastern end of Feature 102 and overlying colluvial material and quarry debris. Note the bed of banded opalite overlain by tuff in the pit wall (compare with Figure 75).

Quarry Deposits of Feature 102

The oldest quarry deposits at Locality 36 fill Feature 102 (cf. Figure 75), and are grouped into three horizons. Sediments of Horizon VI comprise Units 38-51 and Units 110-118 (the latter exposed in Trench 3 Extension). Overlying a surface cut through the paleosol and underlying bedrock in the western half of Feature 102, strata of opalite and tuff debris roughly alternate with silty clay-rich layers. Charcoal is a common component, especially in Units 46, 44, and 42, from which radiocarbon assays produced dates of 3890±60 B.P. (BETA 39485), 3810±60 B.P. (BETA 42474), and 3670±90 (BETA 42476), respectively. These dates are in the proper stratigraphic order, and the oldest and youngest dates fall within two standard deviations of each other. The youngest date is inverted, however, when compared to those from the stratigraphically superior Horizon V described below. The fine grained strata in Horizon VI (and throughout the fill of Feature 102) have weak granular to very weak blocky ped structure, and all the silt loam and clay loam matrix is noticeably red in hue. While redeposited natural surface silt and red clay paleosol may account partially for these attributes, the age of the deposits suggests pedogenisis; they probably have been buried for a long time compared to other quarry debris examples at Tosawihi.

The truncation surface of a later quarry excavation cuts Units 38, 39, 40, 41, and 42 of Horizon VI. This pit is filled with strata of Horizon V (Units 29, 30 31a-f, 32a-b, 33, 34a-d, 35, and 36), alternating fine and coarse units similar to those in Horizon VI. Charcoal also is common in Horizon V. Radiocarbon assays of charcoal in Units 35 and 32b produced essentially the same date: 3830±80 B.P. (BETA 42475) and 3890±70 (BETA 43152), respectively. These dates are similar to those from Units 44 and 46 in Horizon VI. The youngest date from Horizon VI (3670±70 B.P., BETA 42476) is younger than either date from Horizon V, and thus appears inverted. Nevertheless, it falls within one standard deviation of youngest, and within two standard deviations of the oldest dates, from Horizon V.

The youngest truncation surface is a pit excavation that cuts all of Horizon V and represents the latest quarrying episode at Feature 102. Horizon IV is a minor package of quarry debris and slopewash material, consisting of Units 26, 27, and 28a-c. The lowest stratigraphic units (28a-c) are hash, probably produced from battering and flaking tuff around the opalite face, while Unit 27 is a layer of medium to coarse opalite shatter, angular tuff clasts, and rare medium opalite flakes probably produced during toolstone extraction. Stratum 26 is a sandy clay loam (similar to overlying colluvial Unit 19), probably deposited by slopewash after the pit was abandoned.

Colluvial and Other Deposits Over Feature 102

Strata overlying the three horizons of Feature 102 include Unit 37, a silt loam grading to coarse open work down slope. This unit resembles quarry pit debris more than colluvium, but it cannot be assigned to any of the horizons described above. It may be related to quarrying south of Trench 3, since it seems to thicken southward in the west wall (the west end) of that Trench (cf. Figure 75). Unit 121 is a similar lens of flakes and chunks that also may be quarrying debris.

Units 19a-b and 22-24 are predominantly silt and clay loam soil and colluvial deposits that extend upslope over unquarried weathered tuff bedrock separating the quarry debris of Features 102 and 49 (cf. Figures 75 and 78). Unit 19a lies directly on the weathered tuff bedrock between the features, and grades down into it in places. Unit 19b overlies 19a on the bedrock, and fills the Feature 102 pit above Horizon IV. Units 19a and 19b differ mainly by the greater relative abundance of opalite flakes and chunks in 19b which are rare in Unit 19a. Unit 19a is truncated by (and thus predates) the east wall of Feature 102, and probably represents the original colluvial soil cover on the bedrock. The origin of Unit 19b is more enigmatic. One (identified as 19b) overlies 19a on the bedrock between Features 102 and 49. Here it is possible that Units 19a and 19b have the same origin as colluvial soil, and that the opalite flakes and chunks in 19b originated in bioturbation from overlying Unit 22, which is clearly colluvial quarry debris. Deposits of Unit 19b also fill the pit swale in Feature 102 above Horizon IV; this material seems to have originated as spoil from upslope quarrying and was distributed downslope by slopewash and colluvial action, as were Units 22, 23, and 24 above it. Unit 25, a poor to moderate open framework of medium to coarse opalite flakes and opalite and tuff chunks at the surface, probably is a slopewash lag deposit of quarry debris from Feature 49 or an adjacent quarry pit.

Quarry Deposits of Feature 49

Most stratigraphic units filling the arcuate embayment of Feature 49 (cf. Figure 74) are poor, moderate, or typical open frameworks of opalite and tuff chunks and opalite flakes with sparse to abundant silt loam, clay loam, or sandy tuff-hash matrix (cf. Appendix D: Table 12). The open framework deposits are most prevalent in the upper portions of the profile. Nearest the bottom, closer to the soft weathered tuff bedrock, they consist of compact hashes and hash-like materials. The general pattern in the matrix is more silt-rich nearest the top, with sandy tuff-hash matrix more common lower. Three nearly identical radiocarbon dates were obtained from charcoal in units near the pit floor from the south end of Trench 8: 500±50 (BETA 42493), 510±60 B.P (BETA 42494) and 520±70 B.P. (BETA 42497). The earliest date from Feature 49, 920±110 B.P. (BETA 43158) from Unit 62 further north, suggests that quarrying may have moved southerly, but this is not strongly supported by the stratigraphy observed in the east wall profile of Trench 8 (cf. Figure 74).

Although Trench 8 runs directly through Features 48 and 49, the best view of the structure and relative relationships of the stratigraphic units associated with the large adit is provided by the northern wall of Trench 3 (cf. Figure 75); its orientation parallels the direction of progressive uphill quarrying.

The tuff bedrock and clay paleosol (Unit 20) are cut by a truncation surface that forms the eastern wall of the Feature 49 pit. Unit 19a is draped over the clay paleosol and tuff bedrock on the truncation surface, perhaps as slopewash. This suggests that Unit 19a must have been in place before the excavation of Feature 49. It is impossible say whether Unit 19b also was cut by the truncation surface. Deposits of Horizon III overlying Unit 19a and the bedrock surface comprise Units 13-18. Units 13 and 15 are poor open frameworks of opalite and tuff debris, while Units 14, 16, and 18 are typical hashes with varying amounts of opalite flakes and chips. Unit 17 is a charcoal accumulation within Unit 14, but it failed to produce enough carbon for dating. The date of 500±50 B.P. (BETA 42493), from the intersecting wall of Trench 8, however, shares a similar stratigraphic position.

Subsequent quarrying and creation of the present adit produced a truncation surface that cuts all of units of Horizon III. Horizon II deposits (Units 4, 5, 6, 7, 8, 9, 10, 11, and 12) fill this pit and the adit, and can be traced around the corner intersecting with Trench 8. Unit 12, on the bottom, is hash; overlying units alternate silty clays and coarse debris. The slope of the silt-rich units into the adit and opalite face, and their clear individual definition, is typical of most features with quarry debris deposits abutting bedrock faces. The silty and organic-rich appearance of the matrix in these deposits, however, also suggests that slopewash may have contributed a significant component to the fill.

Colluvial and Other Deposits Over Feature 49

Deposits covering Feature 49 include Units 1, 2, 3, 4, 5, and 6. Units 5 and 6 are silt loam slopewash deposits (cf. Figures 75 and 76). Units 4, 2, and 1 are open frameworks of coarse quarry debris probably deposited in the Feature 49 depression as a result of quarrying north or south of the feature. Unit 1 is a sparsely vegetated open framework of coarse opalite and tuff cobbles and opalite flakes that originally helped define Feature 49 from the surface. Unit 2 is similar except for having an abundant silt loam matrix. It may be related genetically to Unit 1 with the silts having infiltrated downward from the surface. Unit 4 probably also is part of Unit 2, but it has a darker matrix due to the infiltration of charcoal and ash from above. Unit 3 probably also is related to Unit 2, but it caps the overhanging bedrock face as well as filling part of the adit cavity. Unit 3 is a mixture of soil and slopewash with common opalite flakes and tuff chunks, but it contains patches of charcoal and ash; some flakes show signs of burning.

Observations of Trench 6 provide a better understanding of depositional and erosional processes at quarry features such as Features 102 and 49. Bedrock occurrence in quarried areas and the modification of bedrock morphology due to quarrying probably affected the deposition of some debris units in quarry pit fill sequences by modifying slope and therefore altering the dynamics of material transport and deposition. For example, the notable thickening of Unit 19 in Trench 3 at its western end where it passes over the quarried opalite face of Feature 102 (described below) probably was naturally thick before quarrying due to the presence of opalite bedrock. Nevertheless, additional quarrying-induced relief probably resulted in an even larger input of disturbed soil and quarry material at the break in slope.

Conclusions

Prehistoric quarrying strategies employed at Locality 36 are revealed clearly in the backhoe trench profiles described above, and the progress of quarrying is reflected in the distribution of radiocarbon dates by area (Figure 79).

The Type 2 setting so common at Tosawihi, where beds of opalite toolstone embedded in softer tuff intersect a sloping surface, offered a relatively low cost opportunity for prehistoric quarriers; it was seized upon about 4000 years ago. The earliest date from Locality 36, however, 4090±100 B.P. (Beta 42159), is enigmatic. The southern portion of Area B probably constituted a Type 2 setting, but it has been modified so extensively by quarrying that no evidence of its original morphology remains. Early quarriers may have been attracted to Area B by the presence of high quality opalite near the surface, naturally fractured by frost and the mechanical action of overlying clay paleosol; toolstone was thus extracted easily. Lying on the surface of scoured opalite bedrock below shallow, churned deposits of quarry debris, the charcoal seems unrelated to adit quarrying, and appears not to reflect an organized hearth. This date may be the only relic of an early intensive episode of bedrock quarrying in Area A, other evidence for which has been destroyed by subsequent quarrying.

Bedrock quarrying began within the next 200 years in Area C at Feature 102. Four radiocarbon dates from this feature cluster tightly between 3810 B.P. and 3890 B.P. (cf. Table 35) in the middle of the No Name Phase (Elston and Budy 1990, Figure 110). Although the youngest radiocarbon date of 3670 B.P. from Feature 102 is stratigraphically inverted, it seems not significantly younger than the other dates. A discrepancy of this magnitude *could* arise from the burning of old growth sagebrush at the commencement of quarrying and the rise of younger plants somewhat later. What perhaps *is* significant, however, is that intensive quarrying seems to have started in the least costly bedrock setting. Work at Feature 102 exploited a seam of high quality opalite intersecting the surface, and was embedded between two layers of relatively soft tuff easily removed to isolate the opalite. The presence of charcoal in the pit suggests that quarrying techniques may have involved driving adits under the opalite and setting fires to detach material, but the bedrock working face is sheer, not undercut; heavy percussion is likely to have been effective here too. The strategy was to work into the slope, and there is no sign of retrograde reexcavation through old quarry debris. The lack of churning suggests that the quarrying venture in Feature 102 was relatively short lived; radiocarbon dates span only 220 years, and the time that the feature actually was worked may have been much less.

Quarrying at Feature 102 stopped, even though it appears that exploitable toolstone remained to be quarried (cf. Figure 78). Although Middle Archaic quarriers may have ceased work for other reasons, it is possible that, compared to other localities at Tosawihi Quarries available at the time, Feature 102 became uneconomical to work further; the overburden above the opalite was about 65 cm thick, 45 cm of which was tuff. In any case, the feature subsequently was filled with and buried by slopewash and colluvium rather than quarry or processing debris. This material lay in and over Feature 102 sufficiently long to be affected by pedogenic processes, and, indeed, appears to have lain undisturbed for nearly 3,700 years. Aside from burial, the reason that Feature 102 was never reworked may owe to its position, farther down the steep slope to the west than the site of any subsequent quarrying activity. Moreover, once the blanket of quarrying debris from later intensive quarrying was established across it, the site may have masked signs of subsurface opalite that once invited early prospectors.

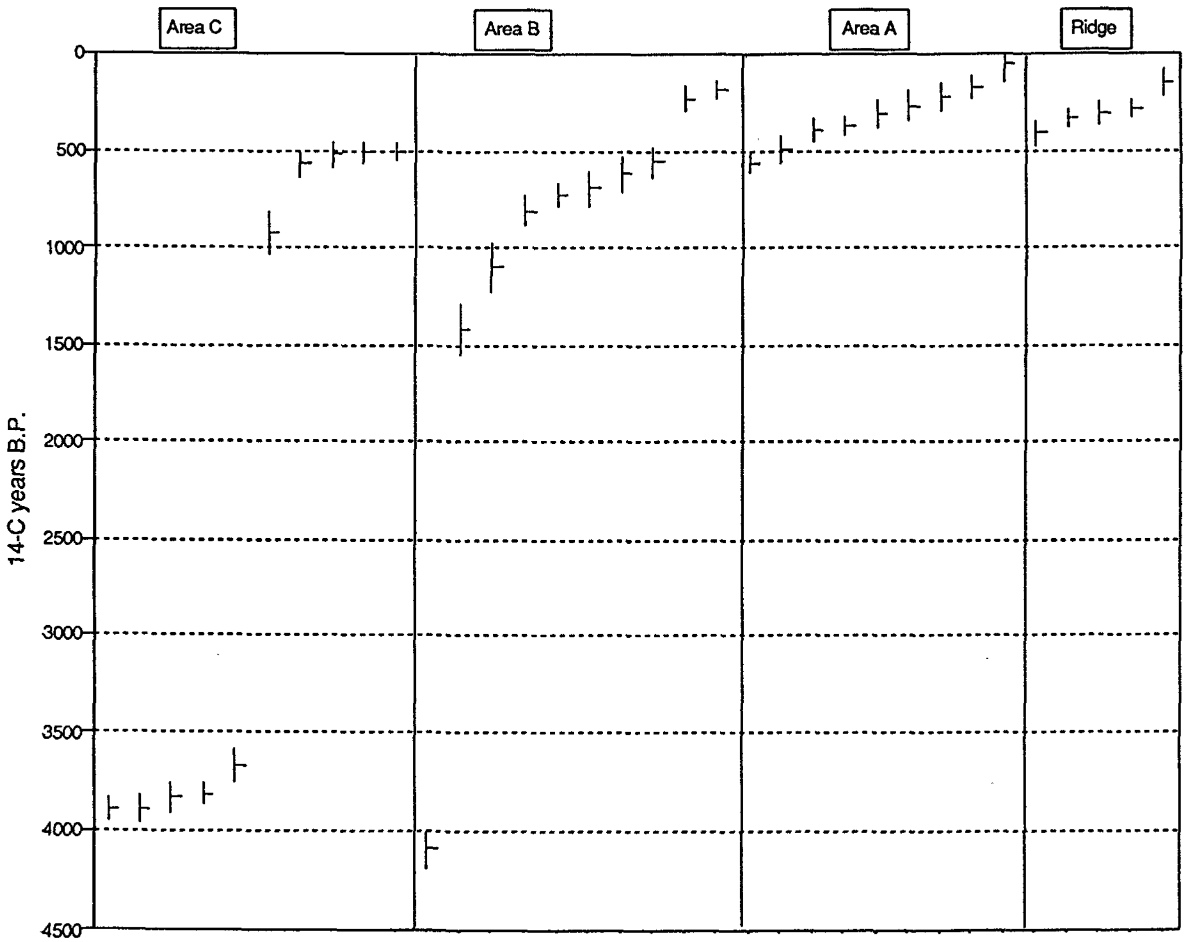


Figure 79. Radiocarbon dates, by area.

The lack of radiocarbon dates between 3,700 B.P. and about 1400 B.P. is difficult to evaluate. While this lacuna may indicate a real break in quarrying activity, previous research (Elston and Drews 1992) suggests no pause in use of the Tosawihi Quarries, but rather a steady increase in the frequency of visitation and the intensity of quarrying, culminating in the Late Prehistoric Period. It also perhaps is equally possible that later intensive quarrying destroyed evidence of earlier activity. This may account for why the earliest radiocarbon date from Locality 36 was preserved in a place where intensive quarrying had *not* occurred. Thus, even the spotty radiocarbon dates between 1420 B.P. and 810 B.P. from Feature 49 in Area C and the southern portion of Area B do not necessarily indicate a period of intermittent quarrying, but merely that radiocarbon dates are more likely to be preserved in younger deposits less prone to disturbance.

The upper opalite bed in Area C may have outcropped at the surface as a Type 1 setting. Feature 49 (and probably the other features in this group) were worked upslope and laterally into the arcuate bedrock face by driving adits along a fractured bedding plane, and by removing tuff above and below the seam. The thicker, more massive beds of opalite in Area B were worked with roughly same horizonal adit technique whenever possible, but vertical crack systems were exploited with pits and benches, producing a large, scoured bedrock depression. Lateral movement across this depression suggests a more opportunistic approach that required frequent re-excavation of older quarry debris and left thoroughly churned deposits yielding few radiocarbon dates earlier than 810 B.P. Indeed, the southern potion of Area B received a kind of persistent attention not afforded opalite elsewhere at Locality 36, reflecting its high value as toolstone.

Quarrying intensity increased during the latter part of the Eagle Rock Phase (Elston and Budy 1990, Figure 110) between 620 B.P. (A.D. 1330) and 220 B.P. (A.D. 1730). Seventeen of thirty-four radiocarbon dates from Locality 36 derive from this period (Figure 80), and four are younger than 190 B.P. (A.D. 1760). Five dates between 410 B.P. (A.D. 1540) and 150 B.P. (A.D. 1800) from hearths on the ridge crest signal late additions to the pattern of site use not previously observed.

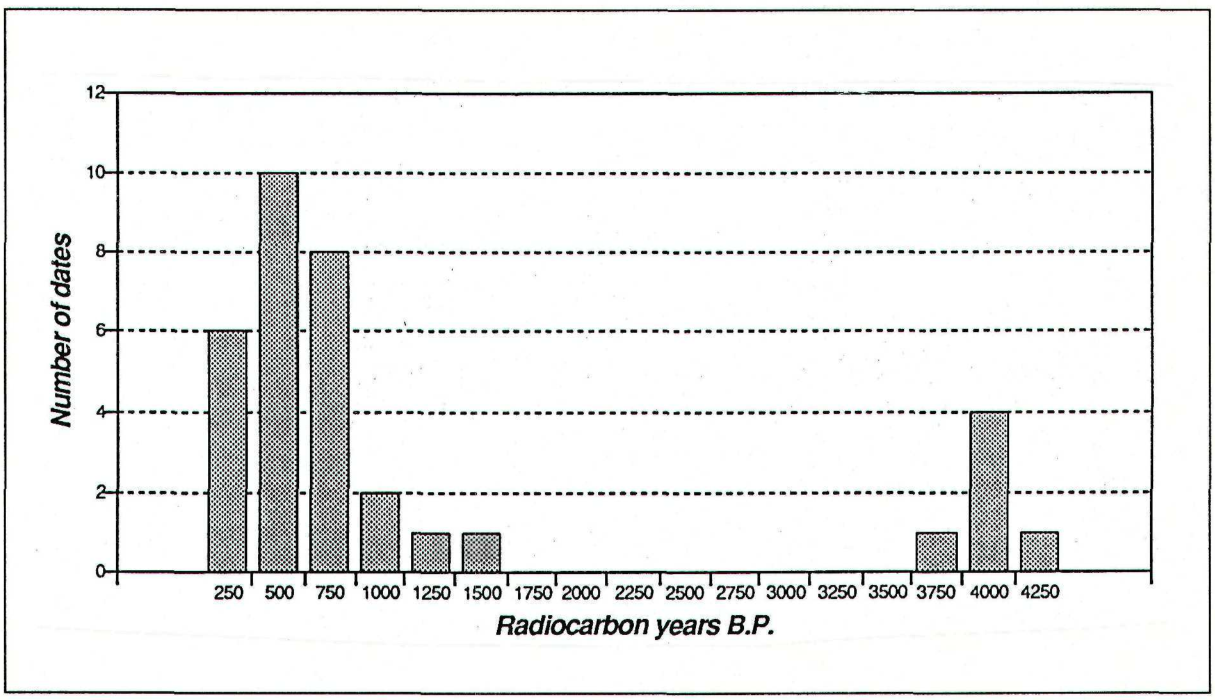


Figure 80. Histogram of radiocarbon dates.

All three quarry areas were utilized, and quarriers worked toolstone that grew more costly to extract through time.

The latest radiocarbon dates from Area C come from Feature 49; they cluster between 570 B.P. and 500 B.P. (cf. Figure 79). The creation of the adit and the abandonment of Feature 49 must have occurred somewhat later. The relatively fresh appearance of quarry debris dumped into the Feature 49 depression suggests that work continued in one or more quarry pits in Area C after Feature 49 was forsaken.

Later radiocarbon dates from Area A begin about the same time as those from Area C, but are not so clustered, extending from 560 B.P. to 170 B.P. (cf. Figure 79); one, only 50 B.P., possibly is the result of recent contamination. The dates and stratigraphy from Area A indicate progressive work into the slope with some lateral movement, but little tendency to work back through old quarry debris. Quarrying probably began in Area A in a Type 2 situation with bedrock near the surface and it terminated 6 meters to the east where the overburden was 1.5 meters or more deep.

Although no radiocarbon dates from Area B fall between 550 B.P. and 230 B.P. (cf. Figure 79), the hiatus may be due more to increased quarrying activity than to abandonment during that time. Although the stratigraphic record from the southern portion of Area B is chaotic, stratigraphy and radiocarbon data further north indicate a general tendency to work into the slope and toward the northeast after 230 B.P.

Thus, stratigraphy and radiocarbon dates reveal some generalized patterns of toolstone exploitation at Locality 36 that vary in time and space. The following chapter explores some economic constraints imposed by the topography of the bedrock and quality of available toolstone that help account for these general patterns.

Chapter 9

BEDROCK TOPOGRAPHY AND TOOLSTONE EXTRACTION

Kristopher R. Carambelas and Robert G. Elston

This chapter considers how the nature of opalite bedrock constrained toolstone extraction at Locality 36. In Chapter 2 we identified several factors of strategic importance including (1) the location of bedrock, (2) the inclination of bedrock relative to ground surface (bedrock setting), (3) the structural features of bedrock, (4) the quality of toolstone and its ease of extraction, and (5) the size and form of toolstone packages which can be procured; together, these factors constitute the *bedrock topography*. We begin this discussion by describing toolstone extraction as it is represented by the ethnographic and archaeological record, and as it can be inferred from experimental quarrying. Next, we examine how bedrock topography affected toolstone extraction. Given our intention to evaluate the model proposed in Chapter 1, we conclude by formulating hypotheses relevant to the benefits and costs of toolstone extraction that can be tested with archaeological data recovered from Locality 36.

Ethnographic and Experimental Toolstone Extraction

Toolstone extraction yields toolstone packages that subsequently are transformed into useful tools. Once prospecting has located a place where lithic raw material can be obtained, overburden or poor quality stone is removed and toolstone is extracted. In order to model how bedrock topography affects toolstone extraction, we rely here on the ethnographic and the archaeological records, as well as on actualistic quarrying experiments.

Toolstone extraction commences with the successful location of places where lithic raw material can be procured. Australian Aborigines (Binford and O'Connell 1984; Jones and White 1988) interested in acquiring subsurface toolstone located such places by observing and testing (assaying) surface material as they walked over the quarry; they also paid attention to places with evidence of previous lithic reduction (Elston and Dugas 1992). Once a promising spot was located, exploration through test pitting followed.

We assume that Tosawihi quarriers followed a similar process, looking for good quality material brought to the surface by colluvial and pedogenic processes (as described in the previous chapter). However, detecting "prospecting" in the archaeological record is problematic since the debris created by prospecting at Locality 36 is likely to be obscured by the debris of toolstone extraction. Therefore, our concern is not with discovering successful prospecting, but with deciphering the location and development of quarry features relative to toolstone-quality bedrock.

How bedrock slopes relative to the surface affects the type of extraction feature likely to be created (cf. Chapter 7:Figure 54; Elston and Dugas 1992) and the technology of extraction. For example, in a Type 1 or Type 2 setting, a layer of toolstone tending toward or intersecting the ground surface presents the quarrier a vertical face of stone. Holmes' (1919) descriptions and illustrations of the Quartzite Boulder Quarries, District of Columbia, and the Mountain of Knives, Mexico, demonstrate that extraction is likely to proceed along the bed horizontal to the surface of the bedrock. On the other hand, bedrock more or less parallel to the ground surface is likely to be extracted from vertical pits as quarriers work down into the bedrock. A good example of vertical pits excavated into a Type 3 bedrock setting is described by Fowke (1902) at Flint Ridge, Ohio (cited by Holmes [1919:176-178, Figure 58]).

The technology of toolstone extraction may be affected by bedrock setting. This appears to be the case for the application of fire and water. Akerman (1979:144) notes that fire was used to fracture the re-silicified surfaces of sandstone in the Kimberley Mountains (Western Australia) in order to access underlying toolstone beds. During actualistic quarrying experiments at Tosawihi (Carambelas and Raven 1991), fire proved useful for removing beds of tuff overlying beds of opalite. The tuff, which usually was reduced to fine powder when hammered, became "welded" and could be extracted in large chunks when fire was applied. Fire did *not* prove useful during our experiments when placed against the vertical face of a quarry pit, however. On the other hand, fires may be lit underneath a bed of toolstone in order to free packages from the parent material, or to break-up large pieces (Binford and O'Connell 1984). Fowke (1902:619-621) interprets the use of fire at Flint Ridge, Ohio, thus:

> He then sunk a pit, as large as he wished, to the surface of the flint. On this he made a fire; and when the stone was hot he threw water on it, causing it to shatter. Throwing aside the fragments, he repeated the process until he penetrated the underlying limestone to a depth which allowed him sufficient room to work conveniently. The top and freshly made face of the flint was thickly plastered with potter's clay, after which fire and water were again utilized for clearing away the limestone until a cavity was formed beneath the flint layer [Holmes 1919:177].

The tool kit used to quarry bedrock is likely to be similar from setting to setting. Pointed digging implements manufactured from antler, bone, and wood (Shepherd 1980:19-20, 28-33), and scoops made from large mammal scapulae (Ahler 1986:75-76; Schmitt 1992a) have been interpreted as tools employed to remove overburden and expose bedrock surfaces. Moreover, these tools probably functioned to loosen and remove debris created by quarrying. Hammerstones and wedges were likely to be used for breaking-up and removing weathered and poor quality stone, as well as for extracting chunks of high quality toolstone from parent material.

We suspect that the bedrock setting of Tosawihi opalite at Locality 36 affected the way in which toolstone was removed and, consequently, the type of quarry features that were formed. In settings where bedrock is more or less parallel to the surface or the slope angle intersects horizontal beds, pits should be the dominant quarry feature; where bedrock trends away from the horizontal, adits should be dominant.

As quarriers attempt to extract toolstone, they are apt to recognize structural features of the bedrock that facilitate toolstone removal. Tuman quarriers were reported to work the weak planes of a bedrock face until the planes were widened and large amount of axe stone was brought down (Burton 1984:241). Carambelas and Raven (1991) found that opalite bedrock which exhibited at least some degree of fracturing could be removed, but that massive, high quality opalite bedrock located in abandoned quarry features was impenetrable. In their experiments, small one-handed hammerstone were used to force wedges made of wood, bone, and antler into fractures of the bedrock; the same hammerstones were also used to loosen packages by light-to-moderate tapping. At Locality 36 we are interested in examining the relationship between structural features of toolstone and the location of quarry features; if appraisals from experimental quarrying are valid, we should expect to see quarry features most developed in areas where structural features facilitate extraction, and less developed in areas where opalite beds are less structured or "massive."

Toolstone quality and ease of extraction are factors upon which toolstone extraction is dependent. Subsurface bedrock is generally higher in quality than surface material, since it has been protected from the effects of weathering (Wilke and Schroth 1989:152). However, high quality toolstone is not necessarily distributed uniformly throughout a bedrock deposit. For example, the Tuman axe makers spent upwards of one month removing stone from a bedrock face in order to expose fresh axe stone (Burton 1984:242). On the other hand, high quality stone may be so difficult to remove (as in the case of the massive opalite encountered during actualistic experiments) that usable toolstone packages may never be extracted. Thus, there appears to be a trade-off between toolstone quality and ease of extraction. For one of the quarry pits studied by Fowke ([1902:619-621] cited in Holmes [1919:177]) at Flint Ridge, Ohio, he noted: "Where the flint was well suited for the purpose intended, or was easily worked, the excavation was carried along in the form of a trench, the waste material being thrown to the rear; under less favorable conditions, the spot was abandoned." At Locality 36 we want to determine if a trade-off exists between toolstone quality and ease of extraction, and, if so, how it affected the extraction of opalite.

A final consideration in toolstone extraction is the size of extracted toolstone packages, since this variable places limits on the size and form of tools produced and on the technology used to produce them (cf. Chapters 4 and 5; K. Jones 1984). Elston (1992b) estimates that during the replication of bifaces to Stage 3 from blocks obtained during experimental quarrying, up to 95 percent of the block was reduced to lithic debris in order to manufacture the biface. This suggests that a Stage 3 biface weighing 250 gm may have been produced from a toolstone package weighing 5,000 gm, a package some 20 times the weight of the biface.

Bedrock Topography and Toolstone Extraction at Locality 36

The preceding discussion describes ways in which bedrock topography can constrain or facilitate toolstone extraction. Below, we focus our attention on the bedrock of Locality 36. Our model of the effects of bedrock topography on toolstone extraction at Locality 36 suggests that the location of toolstone-quality bedrock determined the location of quarry features, and that the bedrock setting determined the type of quarry feature that would be created. In addition, our model suggests that evidence for the use of structural features (fractures, joints, zones of weakness, etc.) in extraction will be present where toolstone was quarried. We suspect that toolstone quality and ease of extraction are associated positively, and that the size and the form of packages procured from the bedrock placed limits on the size and the morphology of useful tools produced at the site. Methods used to evaluate these propositions are included as a part of the discussion.

Location of Opalite Bedrock

As a result of the volcanic, hydrothermal, and erosional processes that created the bedrock ridge on which Locality 36 is located (Figure 81; cf. Chapter 7), toolstone-quality opalite was not distributed evenly across the locality. It seems reasonable to think that prehistoric quarriers would

Figure 81. Tuff bedrock deposit underlying Locality 36, view of southeast slope cut by road.

have located and developed quarry features in the presence of toolstone since their time and effort would have been wasted working areas where toolstone was absent. Figure 82 illustrates the spatial variation between bedrock outcrops, tuff and opalite bedrock exposed in the backhoe trenches, and quarry features as they were mapped prior to trenching. Solid areas represent trenches in which opalite bedrock was found, while dashed lines indicate trenches in which unsilicified tuff was located. Five unutilized bedrock outcrops also are symbolized on the map. Examining the map, we see that along those trenches in which opalite beds were found, quarry features are closely associated; trenches which exposed unsilicified tuff have no quarry features associated with them. Quarry features are absent near the bedrock outcrops, except at the south end where subsurface features have been excavated adjacent bedrock outcrops; this is explained by the poor quality of stone observed at these outcrops (cf. Chapter 3).

The location of opalite beds, particularly of subsurface opalite bedrock, clearly was a determining factor in the placement and development of quarry features. Thus, the decision to develop a quarry feature was calculated rather than haphazard, and information obtained during the prospecting phase of toolstone procurement influenced decisions about where to excavate.

Bedrock Setting

We have suggested that the location of opalite relative to poorly silicified tuff determined where quarry features would be located and developed. We also suspect that, once located, the bedrock setting of the opalite determined the way in which toolstone would be extracted and, consequently, the type of quarry feature that would result. As we use the term here, bedrock setting refers to the inclination of the toolstone bedrock relative to the slope of the ground surface. We employ the typology presented in Chapter 7 (Figure 54) to distinguish three types of bedrock settings (Types I, II, and III), and we note that each type appears to be more or less amenable to the formation of particular quarry features.

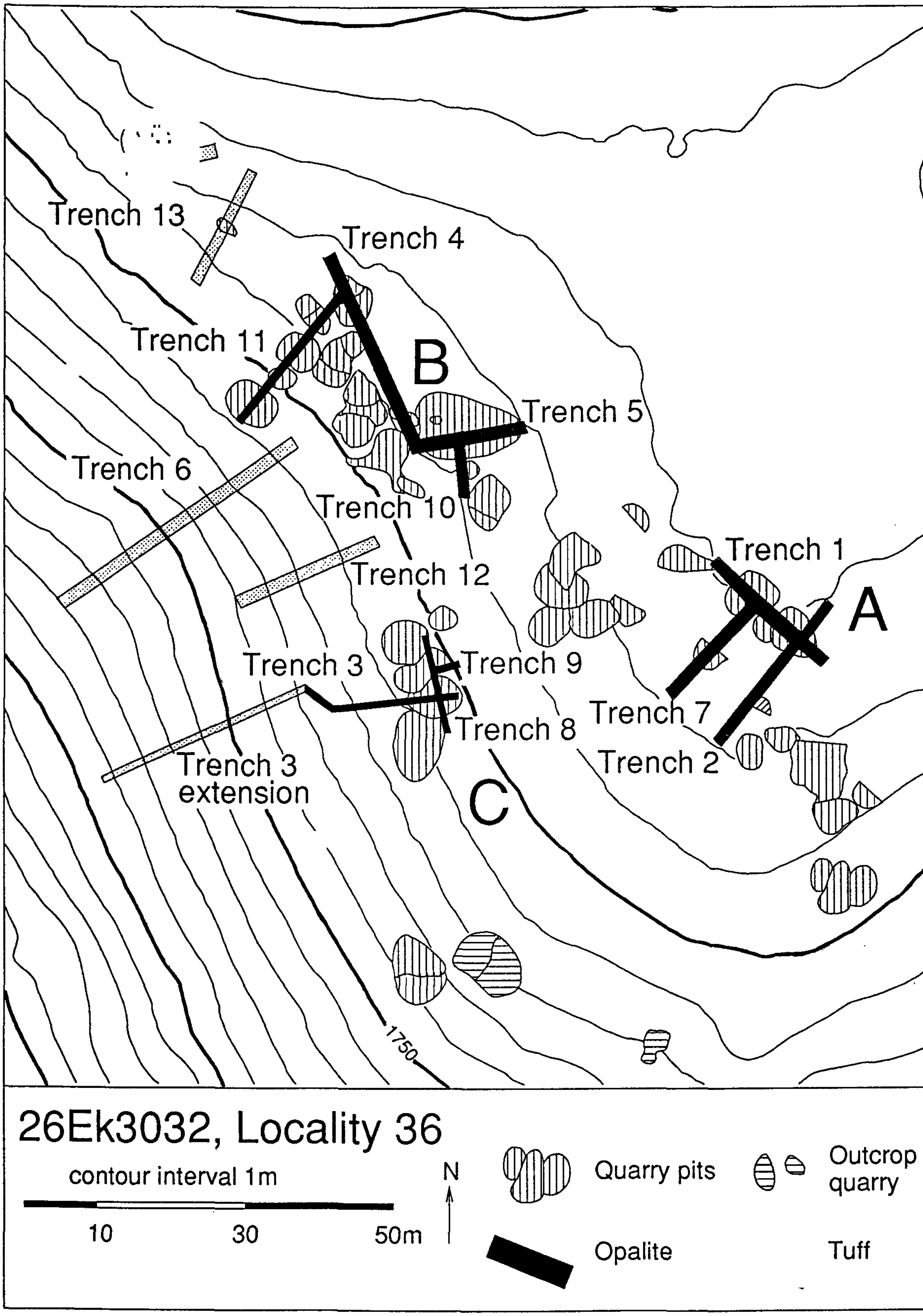


Figure 82. Topographic map of Locality 36 illustrating the relationship between outcropping bedrock, beds of tuff and opalite, and quarry features.

In a Type I setting, bedrock is positioned so that it intersects (outcrops) the ground surface. Intuitively, it seems likely that toolstone extraction would have proceeded by quarriers working back the face of the outcrop and creating adits (cf. Figures 70, 75, and 76). Similarly, adit formation might occur in a Type II setting, since toolstone bedrock inclination is tending toward an intersection with the slope of the surface. In a Type III setting, however, bedrock is more or less parallel to the slope of the surface; quarriers would have removed overlying soil and excavated vertically into the bedrock to extract toolstone (Figure 83). Such techniques result in the formation of pits, features that generally are circular with vertical to near vertical walls. A combination of pit and adit features seems to be a possibility when the bedrock setting is transitional between Types II and III, or where vertical pits penetrate sufficiently deep to create vertical faces that then can be worked laterally. To evaluate this hypothesis, we identified the different types of bedrock setting at Locality 36 (cf. Chapter 8) and the quarry features preserved in them.

Ten of 14 backhoe trenches (Areas A, B, and C) exposed opalite bedrock (cf. Figure 82). A Type III setting was observed in Area A and also in the northeastern portion of Area B (primarily Trench 4); moreover, a transition to Type II from Type III was noted in a portion of Area B (Trench 11). In one portion of Area B (Trenches 5 and 10), the topography had been so disturbed by quarrying that the type of bedrock setting could not be identified. A Type II bedrock setting was noted for Area C. The backhoe also exposed 19 quarry features in profile and plan view; of these, 15 (78.9%) were identified as quarry pits, three (15.8%) manifested characteristics of both quarry pits and adits, and one (5.3%) appeared to be an adit. Table 36 presents data relevant to the relationship between quarry feature type and bedrock setting; locational data (Area and Trench) for each feature are also presented.

Of the 15 quarry pits, 13 (86.7%) are associated with a Type III bedrock setting, and two (13.3%) are associated with a Type II setting. Of the three features that exhibit both quarry pit and adit characteristics, one is located in a Type II setting, another in a Type III setting, and one in a

Figure 83. Feature 71 quarry pit.

setting that can not be specified because it is so heavily quarried. The adit was observed in a Type II setting. These data lend support to our hypothesis that the setting in which toolstone is encountered strongly influences the methods used in its extraction and, consequently, the type of quarry feature that is created. Extraction from beds more or less horizontal to the slope of the surface from which quarries work is accomplished by the creation of pits, while extraction from beds tending toward or intersecting the surface is almost certain to create adits; extraction from bedrock intermediate between the two settings is likely to create a combination of both pit and adit features.

Table 36. Bedrock Setting and Quarry Feature Type.

Feature	Bedrock Setting			Quarry Feature Type		Feature Location	
Number	I	II	III	Adit	Pit	Trench	Group
71			X		X	1	A
72			X		X	1	A
73			X		X	1	A
104			X		X	1	A
103			X		X	1	A
111			X		X	2	A
42*		?	?	X	X	5/10	B
22			X		X	4	B
25			X		X	4	B
27			X		X	4	B
112			X		X	4	B
29			X		X	4	B
31			X	X	X	4	B
32			X		X	4	B
35			X		X	4	B
30		X			X	11	B
12		X			X	11	B
102		X		X	X	3	C
49		X		X		3	C

*Large feature encompassing both trenches; bedrock setting could not be determined.

Geological Features of the Bedrock

At Locality 36, quarry features were created by the extraction of toolstone packages from bedrock. While the type of feature (pit or adit) created was due largely to the bedrock setting, other geological features including the differential emplacement of opalite and the structural features of the bedrock influenced the way in which packages were removed.

Opalite Emplacement

Opalite emplacement in the Tosawihi vicinity varied both horizontally and vertically throughout the deposit of tuff. This emplacement also affected techniques of extraction (cf. Chapter 8). For example, quarriers who encountered nearly horizontal opalite beds dug down and laterally into the stone; joints, cracks, and tuff stringers and pockets were utilized to isolate and remove toolstone packages. If, on the other hand, an opalite bed was located above or between beds of tuff, the softer material was undermined in order to create an overhang of opalite from which usable packages could be detached.

Feature 31 (Figure 84), exposed at the junction of trenches 4 and 11 (cf. Figure 82), is a pit and adit feature that provides a good example of this latter technique. Differential silicification of tuff at this place left a lens of opalite situated between deposits of tuff (designated "a" [Figure 85]), above and below, and areas of massive opalite (designated "b" [Figure 85]), which are on either side of the opalite band. Excavations proceeded through much of the tuff in order to extract chunks of the overlying opalite band, and they terminated at places where opalite was too massive or where it did not exist.

Structural Features

While beds of tuff offered prehistoric quarriers one avenue for toolstone extraction, structural features present in opalite beds offered yet another. Fractures are the predominant structural features of opalite bedrock at Locality 36, and their development and distribution across the bedrock is variable. For example, an area of opalite exposed between Features 31 and 29 in Trench 4 (Figure 86) illustrates a typical situation in which large, angular chunks of opalite have been separated from one another by the shrink-swell action of the overlying clay paleosol in fractures. Although significant fractures occur adjacent these chunks, clays have not infiltrated and no appreciable movement has occurred. In both instances, quarriers could have removed chunks of opalite by loosening them with a hammerstone and by driving wooden or antler wedges into the fractures in order to pry the chunks from parent material. The underlying massive opalite (Figure 86, foreground) displays few fractures, and prying chunks away from the bedrock at this place would have been extremely difficult, if not impossible, as demonstrated by experimental quarrying (Carambelas and Raven 1991).

Differential development of fractures was recognized across most of the bedrock, but especially in Trench 4 where large areas of unexcavated opalite were exposed. In Figure 87, a schematic of a portion of Trench 4 produced from a number of sketch maps of quarry features, illustrates the variable distribution of fractures relative to quarry features, massive opalite, and hammerstone scars. Although quarry features obscure the continuation of fractures over stone that once was unquarried, it seems reasonable to suspect that the frequency at which fractures occurred was greater in these excavated areas. Also depicted is the observation that hammerstone scars, visible on unquarried bedrock, are more frequent near areas of greater fracturing than they are in areas where the bedrock is massive. This suggests that quarriers focused their efforts on those places where structural features facilitated toolstone removal, and that they bypassed areas where extraction was inhibited by a lack of structural features.

Toolstone Quality and Ease of Extraction

While the differential emplacement of opalite and the variable distribution and development of structural features either facilitate or impede toolstone extraction, they also contribute to the quality of the bedrock for toolstone. Other features of the bedrock, such as vugs,

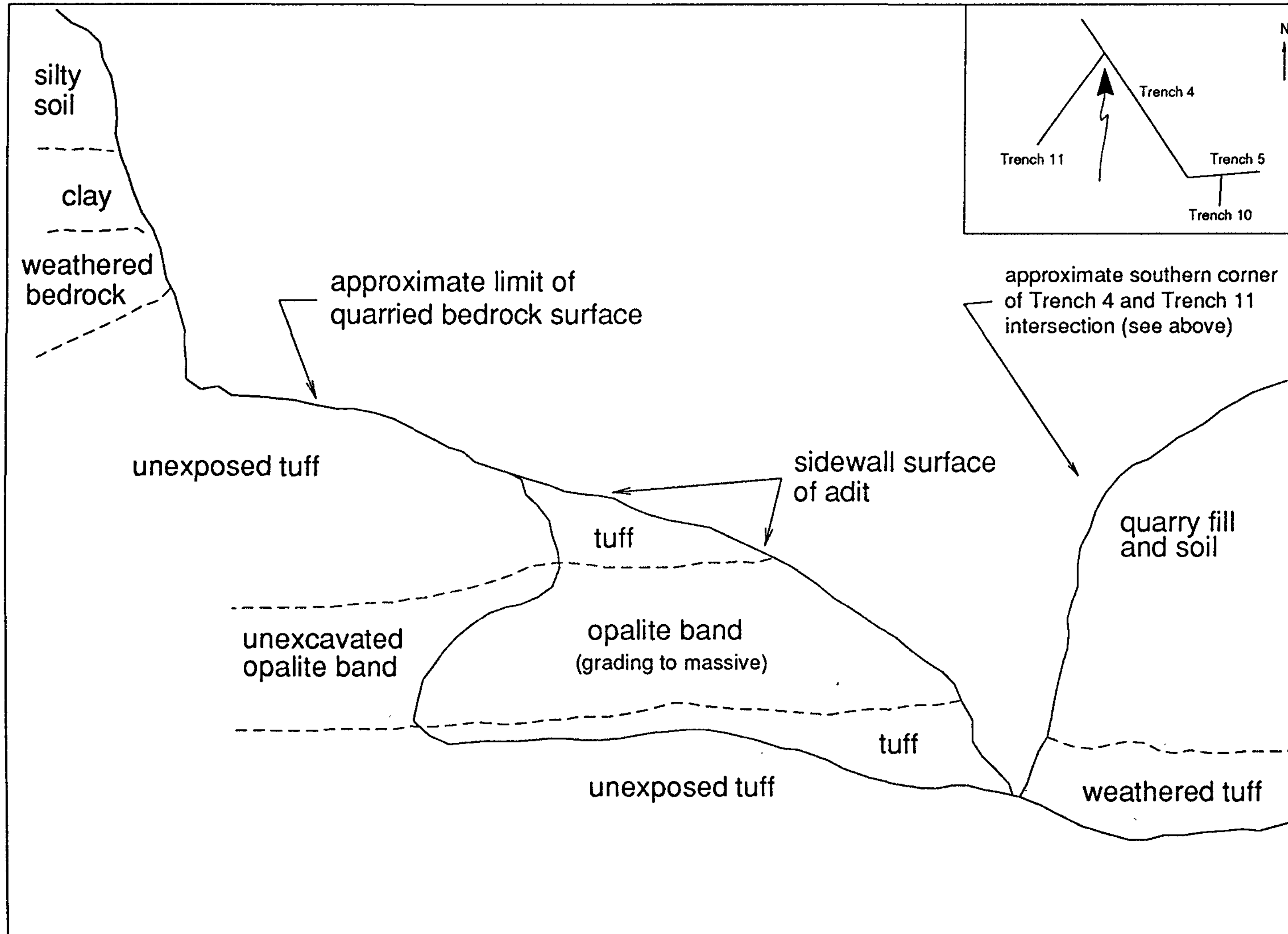


Figure 84. Profile of Feature 31 quarry pit and adit.

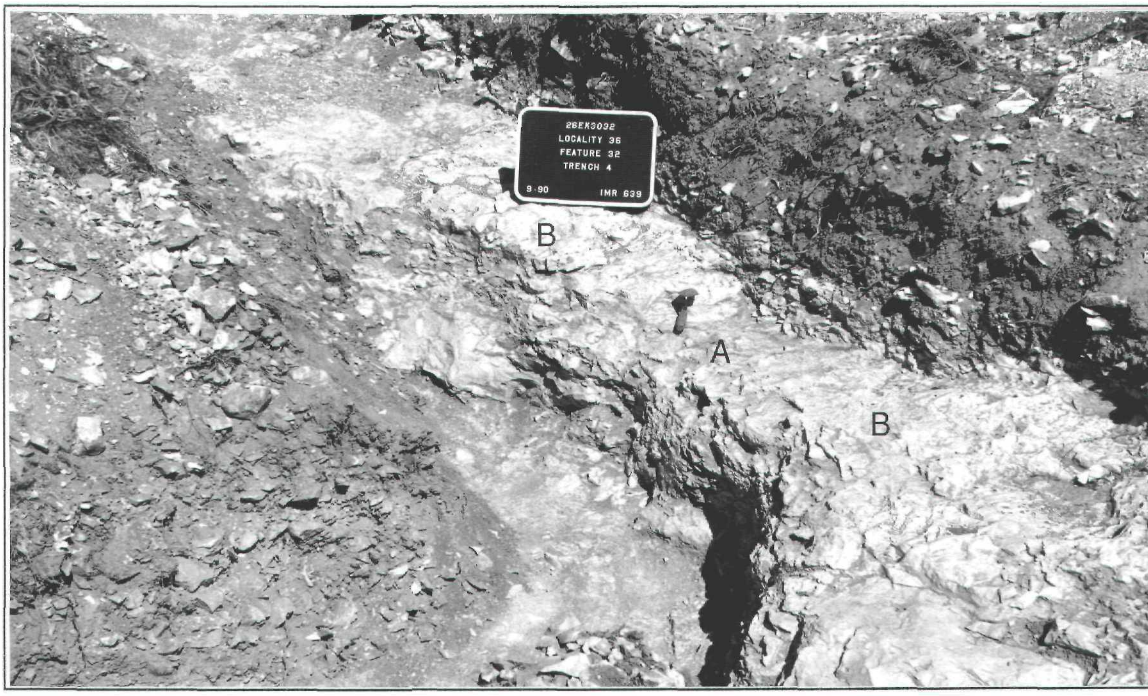


Figure 85. Quarry pit and adit, Trench 4.


Figure 86. Structural features separating opalite chunks from bedrock.

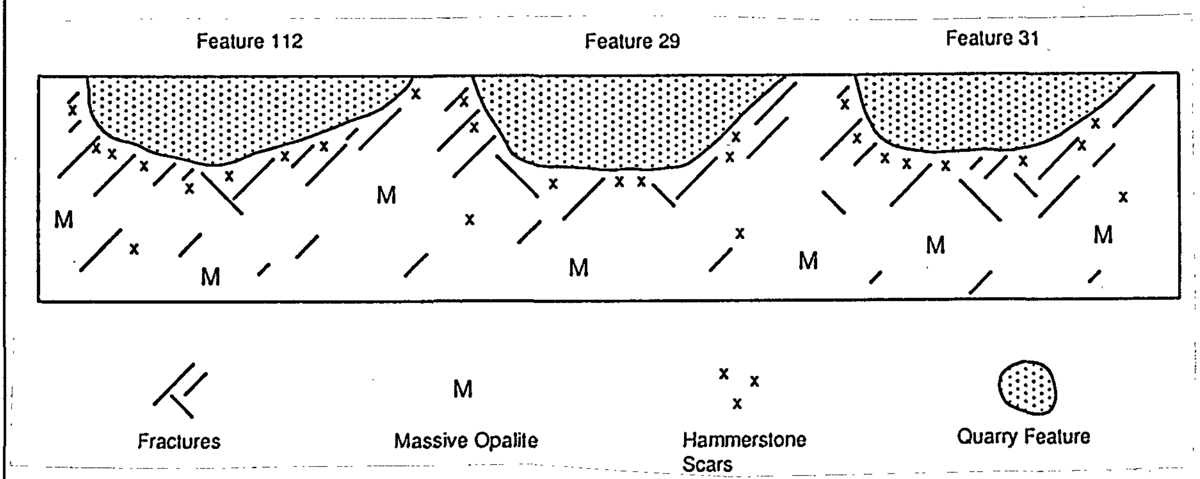


Figure 87. Schematic of Trench 4 illustrating the relationship between structural features, massive bedrock, quarry features, and hammerstone scars.

also affect quality. These observations lead us to propose that a relationship exists between the quality of opalite beds for toolstone at Locality 36 and the ease with which that toolstone can be extracted; specifically, where toolstone quality is poor, extraction is likely to be relatively easy, and where toolstone is excellent, extraction is likely to be very difficult. In order to evaluate this hypothesis, a lithic specialist assessed both quality and ease of extraction of bedrock opalite exposed in the backhoe trenches of Locality 36.

Observing opalite beds and quarry features in selected trenches (1, 2, 3, 4, 5, 7, 8, 10, and 11; cf. Table 37), the lithics specialist judged toolstone quality in terms of the observed "texture" of the bedrock, that is, the general appearance or the character of the lithic resource (Mark Moore, personal communication 1991). Areas of the bedrock then were ranked and mapped; rankings included Poor (0.0-0.9), Below Average (1.0-1.9), Average (2.0-2.9), and Above Average (>2.9). Opalite receiving the highest rank was that which exhibited the greatest amount of textural homogeneity; tuff stringers and pockets, cracks, vugs, and other inclusions were noticeably absent. Opalite receiving the lowest rank was that which manifested the greatest amounts of textural heterogeneity; or, it contained many of the features described above.

Ease of toolstone extraction was judged in a similar fashion; bedrock was ranked and mapped as Very Difficult (0.0-0.9), Difficult (1.0-1.9), and Least Difficult (>1.9). Massive opalite was considered the most difficult to extract, while opalite exhibiting well developed structural features or large pockets or stringers of tuff was considered the least difficult to extract. Figure 88 illustrates how each trench was assessed.

None of the maps produced by the lithics specialist was drawn (to scale), which precluded our use of rigorous quantitative techniques in evaluating our hypothesis. Therefore, for each of the trenches assessed, we compared, qualitatively, toolstone quality maps against the maps for ease of

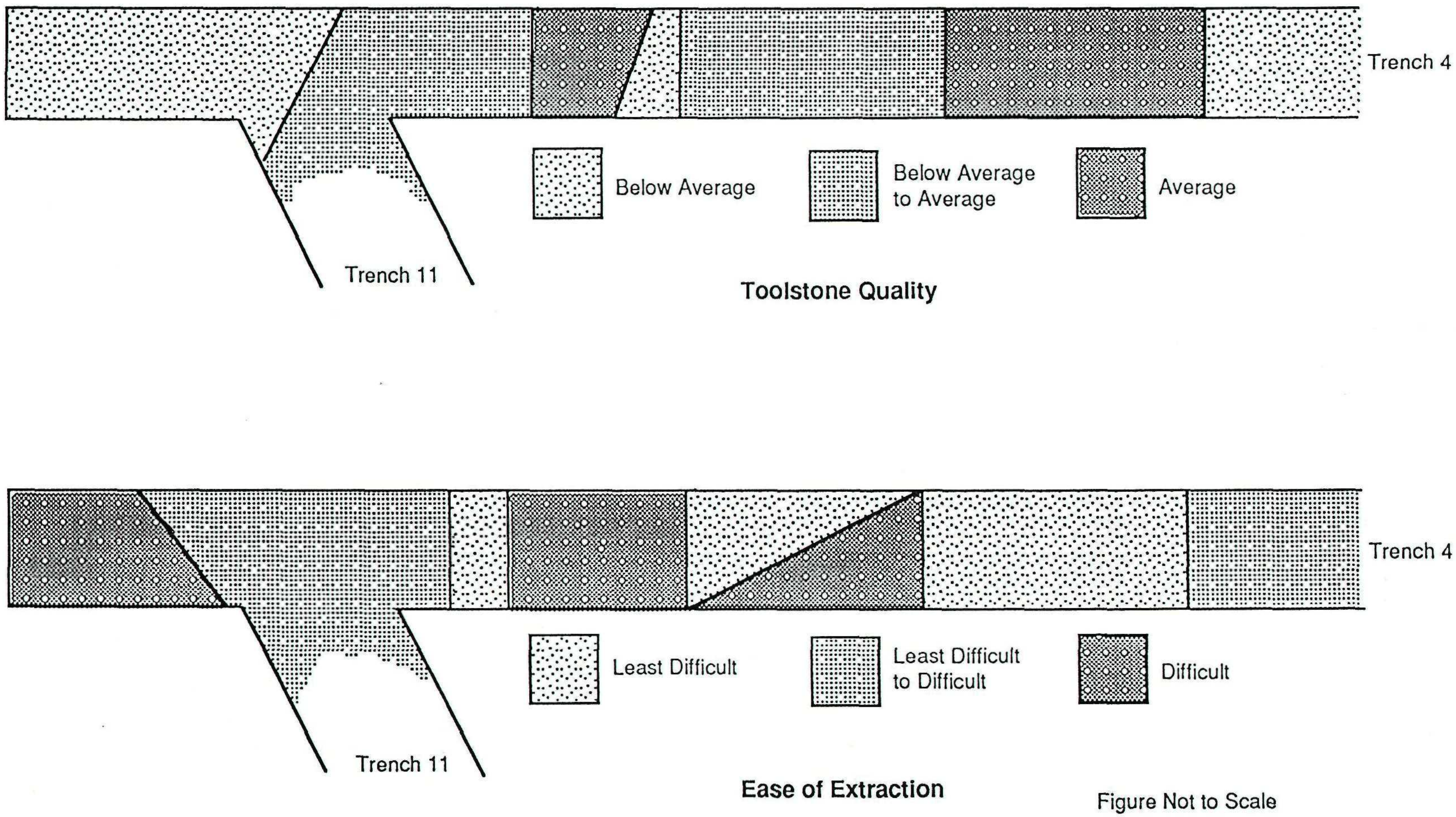


Figure 88. Characterizations of toolstone quality and ease of extraction; example from Trench 4.

extraction. That is, for each area encompassed by a particular toolstone quality ranking, we observed and tabulated the ease of extraction rankings occurring within that area. The results of this analysis, cross-tabulated in Table 37, point up results we expected: as toolstone quality grades from poor to above average, ease of extraction grades from least difficult to very difficult. We suspect that had we been able to use more rigorous quantitative methods, an even stronger relationship would have been demonstrated.

Table 37. Cross-Tabulation Between Toolstone Quality and Ease of Extraction.

	EASE OF EXTRACTION							
	Very Difficult		**Difficult**		**Least Difficult**		**Total**	
	n	Row %	n	Row %	n	Row %	n	Row %
Toolstone Quality	Col. %	Cum. %	Col. %	Cum. %	Col. %	Cum. %	Col. %	Cum. %
Above Average	3	75.0	1	25.0	0	0.0	4	100.0
	33.3	5.1	2.8	1.7	0.0	0.0	6.8	6.8
Average	4	16.0	18	72.0	3	12.0	25	100.0
	44.4	6.8	50.0	30.5	21.4	5.1	42.4	42.4
Below Average	2	9.5	13	61.9	6	28.6	21	100.0
	22.2	3.4	36.1	22.2	42.9	0.2	35.6	35.6
Poor	0	0.0	4	44.4	5	55.6	9	100.0
	0.0	0.0	11.1	6.8	35.7	8.5	15.3	15.3
Totals	9	15.3	36	61.0	14	23.7	59	100.0
	100.0	15.3	100.0	61.0	100.0	23.7	100.0	100.0

Earlier in this chapter we suggested that, during toolstone extraction, quarriers are likely to be faced with a trade-off between toolstone quality and the ease with which that toolstone may be extracted. For instance, massive opalite may be the highest quality toolstone available, yet the efforts of quarriers to pursue such stone may come to naught. On the other hand, toolstone may be very easy to extract, but its poor quality may frustrate attempts to produce tools. Later, in Chapter 12, we attempt to estimate return rates for the different quality rankings we have described; using these return rates we predict which places ought to manifest the greatest amount of toolstone extraction and which places ought to be ignored.

Toolstone Packages

Bifaces of a certain size and form were the goal of tool production at Locality 36 (cf. Chapters 4 and 5). Therefore, it was incumbent upon those who extracted toolstone to recover packages of sufficient size and shape to produce the desired biface. Here, we estimate the minimum dimensions and weight of toolstone packages used to produce bifaces that were eventually transported from Locality 36. We draw from our actualistic quarrying experiments, as well as from replication experiments, in order to make our estimates.

Two of five quarrying experiments conducted at the Tosawihi Quarries were performed at Locality 36 (Carambelas and Raven 1991; Elston 1992b). One experiment estimated rates of overburden removal from a filled-in quarry feature, while the other estimated toolstone return rates from bedrock. During the latter experiment, 61 blocks of opalite were extracted from the bedrock and subsequently were used in replication experiments. Of these, Elston (1992b) reports that 18 were rejected because they were "too small" (mean weight 577.78±264.7 g), and 14 were discarded because they were of poor quality. Twenty-nine blocks were retained for replication (mean weight 1907.14±1458.9 g); 19 either failed or could be reduced only to Stage 2 of the biface continuum, while 10 were reduced successfully to Stage 3 bifaces. The knapper was able to produce 11 Stage 3 bifaces from the remaining 10 packages, however. Our concern is with estimating the weight and dimensions of packages that produced bifaces which were likely to leave Locality 36; therefore, we focus our attention on the 10 blocks from which bifaces were replicated.

Table 38 presents dimensional and weight data for the 10 extracted toolstone packages and the 11 replicated bifaces; the amount of waste produced during replication and the percentages of waste-to-tool for each artifact is also provided. Two observations are immediately interesting. First, replicated bifaces are comparable in dimensions and weights to Stage 3 archaeological bifaces collected from Locality 36 (cf. Table 20), and second, an astonishing amount of waste is produced when replications are preformed.

Table 38. Comparison of Toolstone Package and Stage 3 Biface Produced from Package.

Specimen Number	Toolstone Package Wt.	L	W	T	Stage 3 Biface Wt.	L	W	T	Waste (g)	Waste %/ Tool %
1-1	3150	19	16.5	14	310	10.8	9.3	2.9	2840	90.2/ 9.8
1-5	3500	24.5	14.5	11	141	11.8	5.6	1.5	3359	96.0/ 4.0
1-6	1500	21.5	18	3.5	449	17.5	8.3	2.4	1051	70.1/29.9
1-7	1500	16.9	15	6	418	12.8	9.8	2.6	1082	72.1/27.9
2-2	1600	16	12	6.5	288.2	13.5	8.6	2.4	288.2	82.0/18.0
5-4	1050	13	10	8	209.1	11.5	6.9	2	840.9	80.1/19.9
6-1*	3400	16	15	14.5	307	11.9	8.8	2	2863	84.2/15.8
					230	11.4	7.4	3		
6-3	1700	16.5	10.5	9	239	11.8	7.8	1.7	1461	85.9/14.1
19-1	1350	19	16.5	5	272.6	13.8	7.5	2.6	1077.4	79.8/20.2
20-1	900	14	10	7	87.7	10.8	4.5	1.6	812.3	90.3/ 9.7
Totals	19650				2951.6				15673.8	85.0/15.0

Wt. = Weight in grams
L = Length in millimeters
W = Width in millimeters
T = Thickness in millimeters

*Two bifaces produced from one toolstone package

These observations testify to the knapper's ability to replicate archaeological bifaces given a toolstone package of a particular size and weight. More to the point, they offer a means of estimating *at least* the upper dimensional and weight limits of the smallest packages needed to produce the bifaces recovered from Locality 36. For example, bifaces probably were transported from Locality 36 at approximately middle Stage 3, and the mean weight of Locality 36 bifaces of this stage is 247 gm (±171 gm). Applying the total waste-to-tool percentages in Table 38, we estimate that a package weighing approximately 1647 gm was needed to produce a biface of that weight.

Given a range of variation in toolstone package size and weight, it seems reasonable to think that the "smallness" of packages would be more limiting on biface production than the "largeness" of packages. Nevertheless, it is tempting to speculate about the largest package. Elston

(1992b) notes that during backhoe trenching of Locality 36 a boulder weighing probably in excess of 75 kg was extracted and subsequently reduced during replication experiments. Thirteen block blanks (mean weight 4054.17, ±3742.11 gm) and 11 flake blanks (763.64, ±386.06 gm) resulted in the break-up of the large boulder. Although the package was mechanically excavated, it seems likely that parent material would have released a package of this size when sufficient crack systems and/or tuff stringers allowed ingress, particularly when the adit technique was employed.

A final note on package size concerns the windfalls of nature. Field work in the Tosawihi vicinity provided an opportunity to revisit Locality 36 in the spring of 1991, approximately eight months after the field work phase of our data recovery program had been completed. Backhoe trenches left open throughout the fall and winter months allowed opalite beds to be exposed to the effects of freezing and thawing. We noticed that where experimental extraction had failed to recover many blocks the year before, weathering had loosened the blocks sufficiently that they could be removed with only a little effort. Moreover, as we walked across the opalite beds we noticed blocks that had split away from parent material as a result of weathering. Figure 89 is an example of one such block; its material quality is excellent, and the package weighs 1527.6 gm, well within the range required to produce replication bifaces. Thus, packages of various sizes and shapes, which split away from parent material along natural fracture planes, probably were available to quarriers who simply removed the stone from a pit which had been exposed to the elements.

Conclusion

This chapter has attempted to describe how factors governing the nature of opalite bedrock constrained or facilitated toolstone extraction. We identified the factors, referring to them as compromising the bedrock topography, and described their effects on toolstone extraction elsewhere. Projecting from these descriptions, we anticipated what we might see at Locality 36 in terms of the influence of bedrock topography on toolstone extraction. Here, we offer a synopsis of what we observed. Given our understanding of toolstone extraction at Locality 36, and the way in which it was affected by the bedrock topography, we formulate hypotheses that are relevant to cost minimizing/rate maximizing toolstone extraction behavior; these are evaluated in Chapter 12.

The location of opalite beds at Locality 36 determined the placement and the development of quarry features. While this may seem trivial, it is important to recall that opalite beds at the locality are buried, for the most part, which leads us to conclude that prospecting played a significant role in the location of usable toolstone at the locality. Whether quarriers divined toolstone locations, or whether they probed the ground prior to toolstone extraction is difficult to determine, since the abundance of material produced during extraction masks these activities.

Second, depending upon the bedrock setting, toolstone extraction at Locality 36 proceeded in different directions and formed different quarry features. If opalite beds tended toward or intersected the surface from which quarriers worked, then the exposed vertical face was worked back forming an adit. This contrasts somewhat with similar bedrock settings at 26Ek3084 and 26Ek3208, where not only the face was worked back but pits were excavated into the outcrops as well (Elston and Dugas 1992; Leach, Dugas, and Elston 1993). If opalite beds at Locality 36 were nearly horizontal to the working surface, then extraction proceeded downward and pits were formed. In addition, beds of tuff underlying beds of opalite often were undermined in order to isolate ledges of stone from which packages could be extracted. A combination of these activities, applied for a long period in the southern portion of Area B, produced a large depression in the opalite bedrock. During

Figure 89. Opalite chunk separated from bedrock by natural processes.

extraction, structural features almost certainly facilitated the removal of toolstone while massive opalite inhibited extraction efforts. Too, it is likely that the size and shape of packages procured from the beds determined the size and shaped of bifaces that eventually were transported from the locality.

We demonstrated that toolstone quality and ease of extraction are associated positively. Based upon the observations of a lithics specialist, massive, high quality toolstone beds are the most difficult places to undertake extraction; tufaceous beds, or beds exhibiting well developed fractures contained the poorest quality of toolstone packages, yet these packages are least difficult to extract. Thus, quarriers faced a trade-off between toolstone quality and ease of extraction.

One goal of this report is to evaluate the lithic procurement model outlined in Chapter 1. We assume that toolstone extraction, as a component of the lithic production system, involves some of the highest costs of lithic procurement. Therefore, it is reasonable to expect that this component of the system should evidence some of the most cost-effective and rate-maximizing behaviors; two of these are likely to include the selection of toolstone beds, based upon the amount and kind of overburden overlying them, and the selection of toolstone from places in the bedrock according the return rate which that place yields.

Locality 36 is covered by colluvium and soils of various depth and consistence (cf. Chapter 7). Moreover, with the possible exception of one of the bedrock settings at the locale (cf. Chapter 8, Area C), toolstone beds were all subsurface. Analysis of radiocarbon dates and stratigraphy presented in the previous chapter suggested that toolstone extraction commenced where toolstone beds could be accessed with the least effort, and proceeded thereafter to beds where extraction required more time and effort. In Chapter 12, we examine this hypothesis in terms of another line of evidence: regarding the nature of deposits overlying toolstone, we calculate which of them could have been removed quickest, and determine those places where toolstone extraction most likely commenced.

Once beds are exposed, a second way in which quarriers could have maximized toolstone extraction rates would have been to focus on those area of the bedrock that returned to them the greatest amount of usable toolstone packages per unit of time. Therefore, we propose that quarriers may have compromised toolstone quality for ease of extraction, but only to the point where usable stone remained obtainable. In Chapter 12, we calculate rates of extraction among quality rankings of stone and evaluate which of those places across the bedrock was quarried most intensively.

Chapter 10

DISTRIBUTION STUDIES

Eric E. Ingbar

This chapter examines the spatial distribution of artifacts and features at Locality 36. Our purpose is to elucidate *site structure*: patterns in the spatial occurrence and covariation of artifacts and features.

Several different sets of data are used here to examine spatial patterning. First, feature distributions are examined. Features, especially ones as large as quarry pits, serve as fixed points which constrain how space can be used by site occupants (Binford 1983). Second, the distribution of debitage is studied. Since debitage is the most frequent artifact class, its distribution constitutes a spatial "signature" of the site. As well, the spatial occurrence of debitage attributes yields several patterns interpretable in terms of where different technological acts most often took place. Third, the distribution of a single distinctive variety of local opalite is examined. The purpose of this examination is two-fold: to see how far material from a specific source was transported and to determine whether its use can be considered a chronological marker. Fourth, the spatial distribution of tools is discussed. The occurrence of the two most frequent tool classes—bifaces and hammerstones—is studied and some of their attributes are discussed. Fifth, spatial variation in assemblage contents from three quarry pit complexes (cf. Chapter 9) is used to delineate how areas that probably had similar functions differ from each other. Linking the patterns found in the preceding studies is the subject of the concluding discussion, which considers both how Locality 36 was used by its prehistoric occupants and the spatial structure of quarry/workshop locales in general.

Feature Distribution

Pre-existing features and other non-portable artifacts of human action often determine how site space is used (Bartram, Kroll, and Bunn 1991; Binford 1978, 1983; O'Connell, Hawkes, and Blurton-Jones 1991; Gregg, Kintigh, and Whallon 1991). In this light, Locality 36 features are examined in relationship to each other and to local topography.

Surface Features

The distribution of quarry features at Locality 36 is conditioned by accessible opalite deposits in the western portion of the site (Figure 90). Most quarry pits occur in clusters or complexes of many adjacent pits. Debitage aprons (cf. Chapter 3) surround the pit clusters.

Reduction features/lithic scatters dominate the central flat ridge top where six of the largest lithic scatters are located. Smaller lithic scatters occur in almost every other topographic setting in the site. The debitage aprons undoubtedly contain reduction features/lithic scatters comparable to those we were able to recognize as discrete, so that, in a sense, debitage aprons can be considered high density rings of reduction features around and within quarry pit complexes.

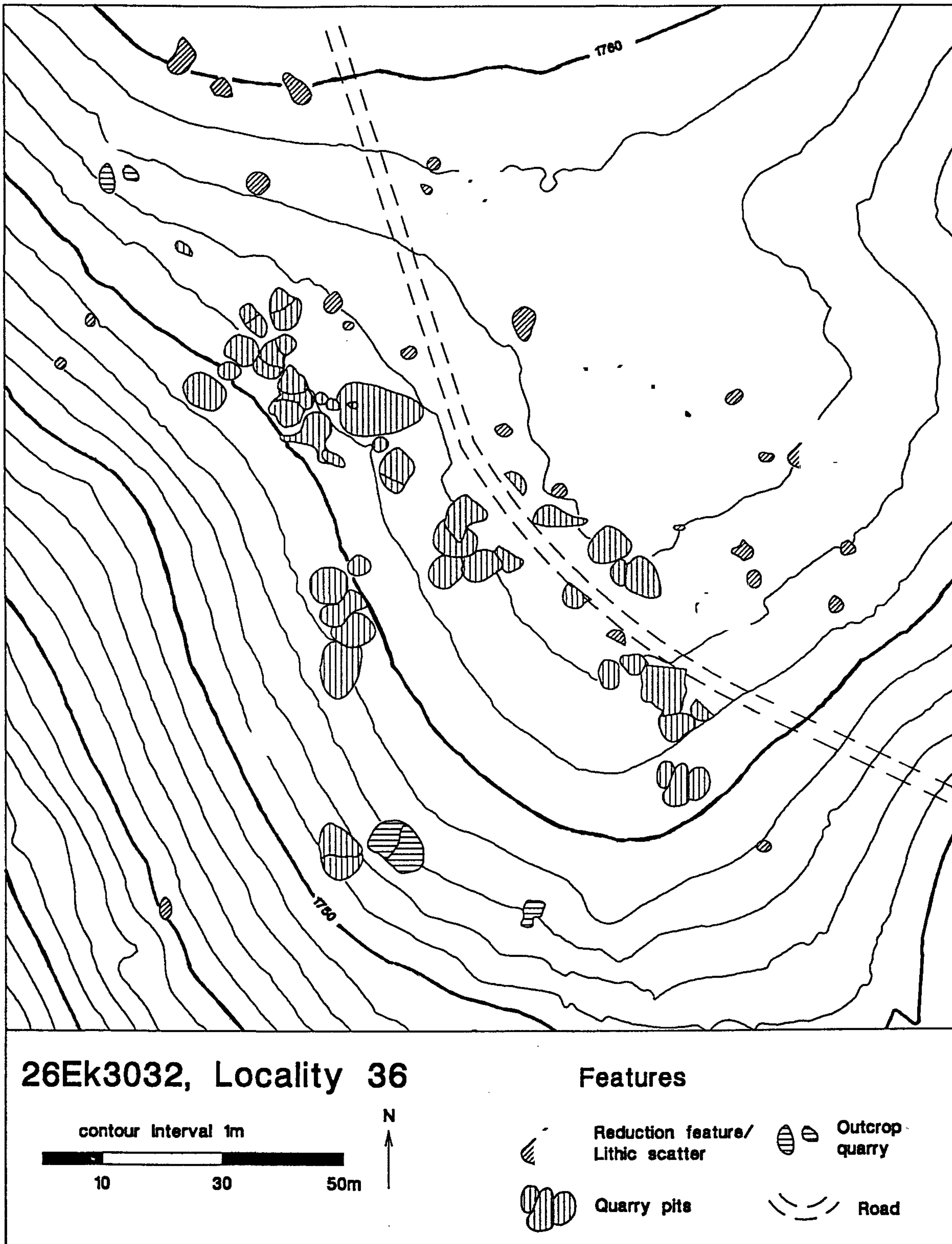


Figure 90. Feature distributions.

The ethnographic literature on quarrying suggests that toolstone extraction localities should exhibit associated reduction areas (Burton 1984; Jones and White 1988; cf. Elston and Dugas 1992). During use of a particular toolstone source, "satellite" reduction features/lithic scatters are created by the work party as they find suitable locations for reducing toolstone blocks. At Locality 36, reduction features/lithic scatters are visible only outside the debitage apron areas, but their distribution relative to quarry pits still can be examined. Figure 91 records the distance from each reduction feature margin to the nearest quarry pit margin. Two distributions of distance to nearest quarry pit are apparent, one consisting of features 2 to 10 meters from nearest quarry pits and a second of features 10 to 30 m distant. Were individual reduction features distinguishable within debitage aprons, a much higher frequency of near neighbors doubtless would emerge. The two modes may indicate a generally organized use of space within the site. Reduction features/lithic scatters within 10m of quarry pits may have resulted from reduction immediately associated with quarrying, perhaps occurring simultaneously. More distant scatters also may have been associated with quarrying, but could represent later reduction, as knappers chose comfortable spots in which to continue work outside quarrying locales.

Topographic relationships include the coincidence of quarry pits and debitage aprons with the western ridge slope (where exploitable opalite is located) and the extensive use of the broad, flat ridgetop for lithic reduction following toolstone extraction. As discussed above, the two relationships are mutually conditional. That is, reduction features/lithic scatters may be more evident east of the quarry pits because debitage aprons are more common west of them.

The distribution of surface features at Locality 36 may constitute a useful comparative case for the study of other sites. The debitage aprons make it impossible to see spatial distributions akin to ethnoarchaeologically described discrete quarrying episodes, but there is structure to their distribution. Quarry features appear embedded in a high density of debitage, and small "islands" of debitage occur further away. This spatial arrangement may well be a signature of long-term or

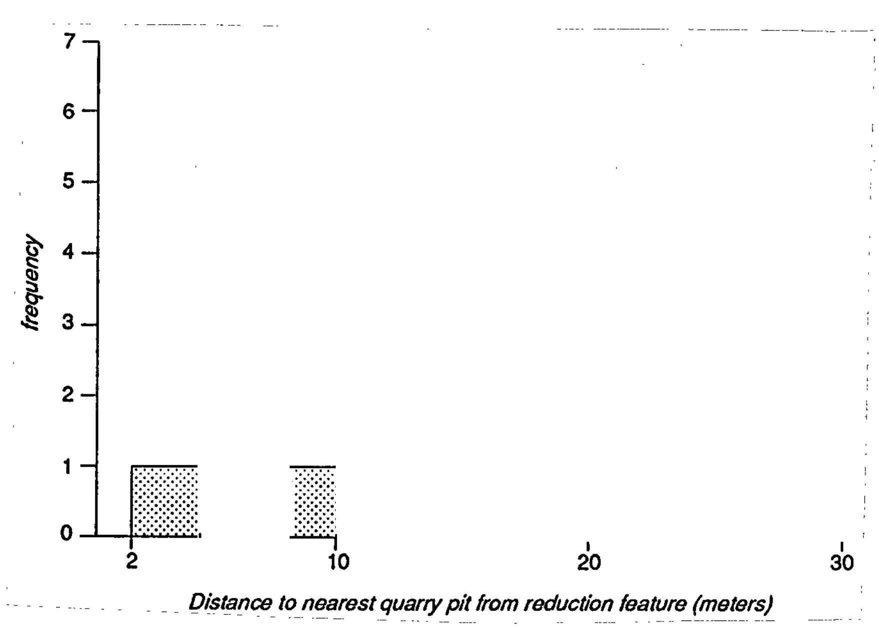


Figure 91. Histogram of distances from reduction feature margins to nearest quarry pits.

intense quarry use, and therefore may produce an index useful in studying other quarry areas through intensive surface recording.

Subsurface Features

The recognized distribution of subsurface features is conditioned, of course, by where we dug, and we found buried features only with mechanized equipment. Because we placed backhoe trenches purposefully, the buried quarry pits and adits found in or near surface quarry pits are not very useful for distributional studies; their distribution simply confirms that where there is one quarry feature there likely are more (cf. Chapter 9). However, we also used a road grader to remove surface sediment from the ridge, and this revealed a set of subsurface features useful for spatial studies because the area scraped was extensive. One surface reduction feature (Feature 70) was found to be a buried quarry pit and six hearths, the only ones found at the locality, were discovered.

The depth of sediment overlying the features was variable; Features 105, 106, 107, and 109 (Figure 92) were discovered between 10 and 20 cm below the modern surface, while Features 108 and 110 were found at 5 to 10 cm (cf. Figure 23). Since the stratigraphic levels of origin were destroyed by grading, assessment of the association between hearths and surface lithic scatter features is difficult. Two hearths (Features 106 and 109) fall within the boundaries of reduction features defined on the original ground surface. Neither surface feature (Features 65 and 69) was explored with excavation units, so the depth of debitage distributions in them is unknown. However, since the surface reduction features/lithic scatters tested on the ridge top proved to contain artifacts to at least 10 cm below surface, it is possible that Features 106 and 109 are associated with surface lithic scatters.

Radiocarbon assay yielded dates of 410±60 B.P. from Feature 106 (Beta-42488), 330±50 B.P. from Feature 105 (Beta-42487), 310±60 B.P. from Feature 109 (Beta-42490), 280±50 B.P. from Feature 107 (Beta-42489), and 150±70 B.P. from Feature 110, the possible hearth (Beta-42491). Depth correlates roughly with age (cf. Figure 23); the three most deeply buried features are the oldest, and the shallowly buried feature is the youngest. Feature 108 was not assayed, but, since it was shallow, we suspect it to be quite young.

A quarry pit adjacent surface Feature 70 (a reduction feature/lithic scatter) also was uncovered by grading. The quarry pit apparently was covered by approximately 10 to 20 cm of surface sediment. No further investigation of this feature was undertaken. Since no data are available on it, it has been omitted from analysis and Feature 70 is still considered a reduction feature for analytical purposes.

Debitage Distribution

We examine two aspects of the Locality 36 debitage assemblage. The distributions of flakes (regardless of technological characterization), flake attributes and angular debris are described. Second, we describe technological characterizations (cf. Chapter 4) in different parts of the site. For the sake of clarity, we briefly restate the conditions under which a sample set was collected; greater detail on particular debitage collection strategies are present in Chapters 3 and 4.

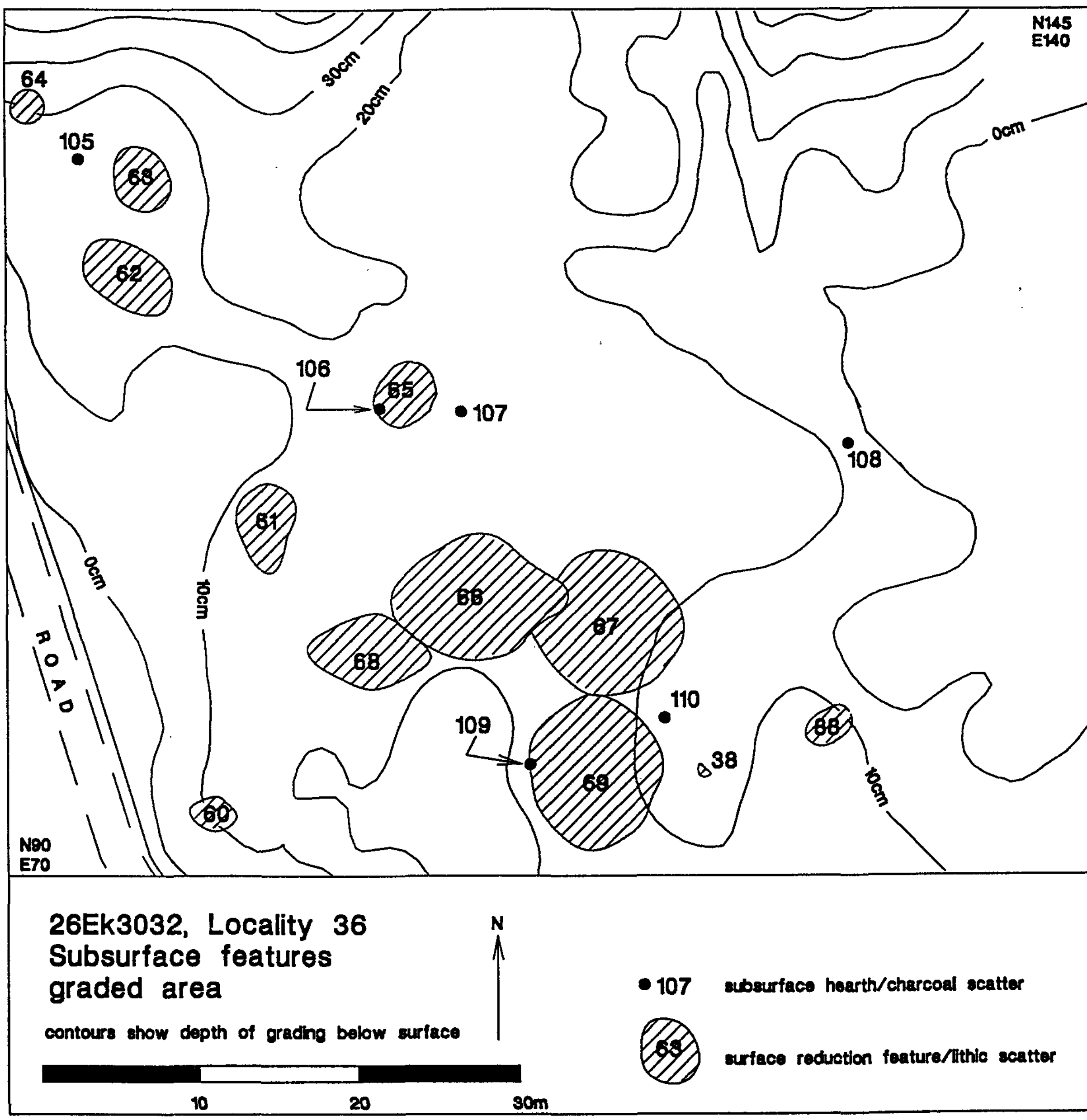


Figure 92. Distribution of subsurface hearth features.

Debitage Size and Frequency Variation

The general distribution of debitage is interesting because it is a major constituent of overall artifact distribution and provides an indirect measure of the frequency with which lithic reduction occurred in different parts of the site over time. For example, if there is a general pattern of reduction within 20 m of quarry pits (creating debitage aprons), a zone of relatively little use 10 to 20 m away from the quarry pits, and sporadic reduction features/lithic scatters greater than 20 m from them, as we have suggested, then this pattern should be apparent in the overall distribution of debitage.

The most appropriate sample set is the locality-wide coverage of 25x25 cm surface scrapes, comprising a systematic random sample of 522 units. Two samples were drawn from random locations within each ten meter block of the site. Sample in roadways were excluded from collection. Each sample was passed through 1/4 in. mesh. Initial analysis consisted of counting and weighing flakes, counting and weighing angular debris greater than 2 in. in maximum dimension, and weighing angular debris smaller than 2 in. in maximum dimension. The sample reflects slightly more than one percent of the surface area of the locality.

The values for each scrape were used to generate contour maps of assemblage attributes. Counts and weights of flakes and angular debris, along with their coordinates in the site grid, became the input data set for isoline map generation. Unlike plotting topographic contours, plotting data values often generates very complicated isoline patterns, a problem exacerbated when variate value distributions are non-normal. To alleviate this while conveying something of the distribution of variate values, all isoline plots of debitage values presented here follow a simple convention whereby contour intervals are based on the quartiles of the distribution. The lowest isoline is the first quartile, the second isoline is the median, the third is the third quartile, and the fourth is the outer fence (the third quartile plus 1.5 times the difference between the first and third quartiles; cf. Fox 1990). The isoline plots of variates convey the spatial distribution of a particular variable's frequency and its distribution. To render differences in values more graphically, wire-mesh plots were generated for some variables.

Flake frequency (extrapolated per square meter; Figure 93) is highest near quarry pits. High flake frequencies are common southwest (downslope) of the quarry pits. Most areas of flake frequency higher than the median value of 420 flakes per square meter are debitage aprons associated with quarry pit complexes. Small higher frequency areas in the center of the northeastern quadrant of the site do not correspond with known feature locations. Since eolian silt tends to accumulate on this ridge top, these may be shallowly buried reduction features/lithic scatters.

The total weight of flakes (extrapolated per square meter; Figure 94) generally reflects their frequency. Again, the highest weights per square meter are associated with quarry features. Figure 95 compares standardized scores (z-scores) for total flake weight subtracted from standardized scores for flake frequency, comparing the two distributions directly by showing differences in both frequency and weight. Negative values indicate areas having heavier than average total flake weights relative to flake frequency, positive values the reverse. Three areas have very high total flake weights relative to flake frequency: around Features 51 and 52, near Feature 9, and an area not associated with any known features in the west central part of the site.

High total flake weight relative to flake count in a sample indicates high *average* flake weight within the sample. When average flake weight is plotted (Figure 96), highest average flake weights correspond to the same three areas mentioned above. Average flake weight is also high in

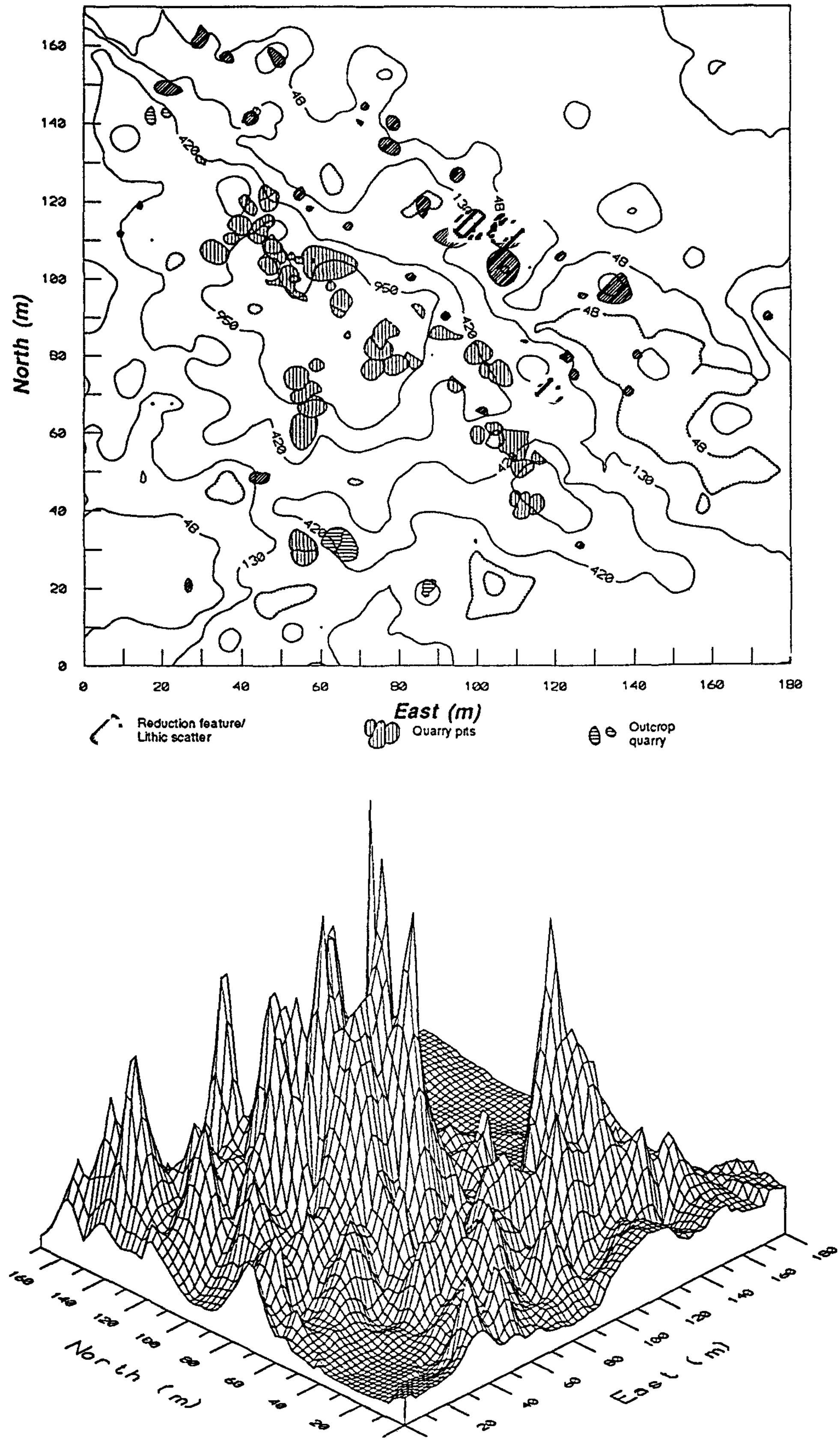
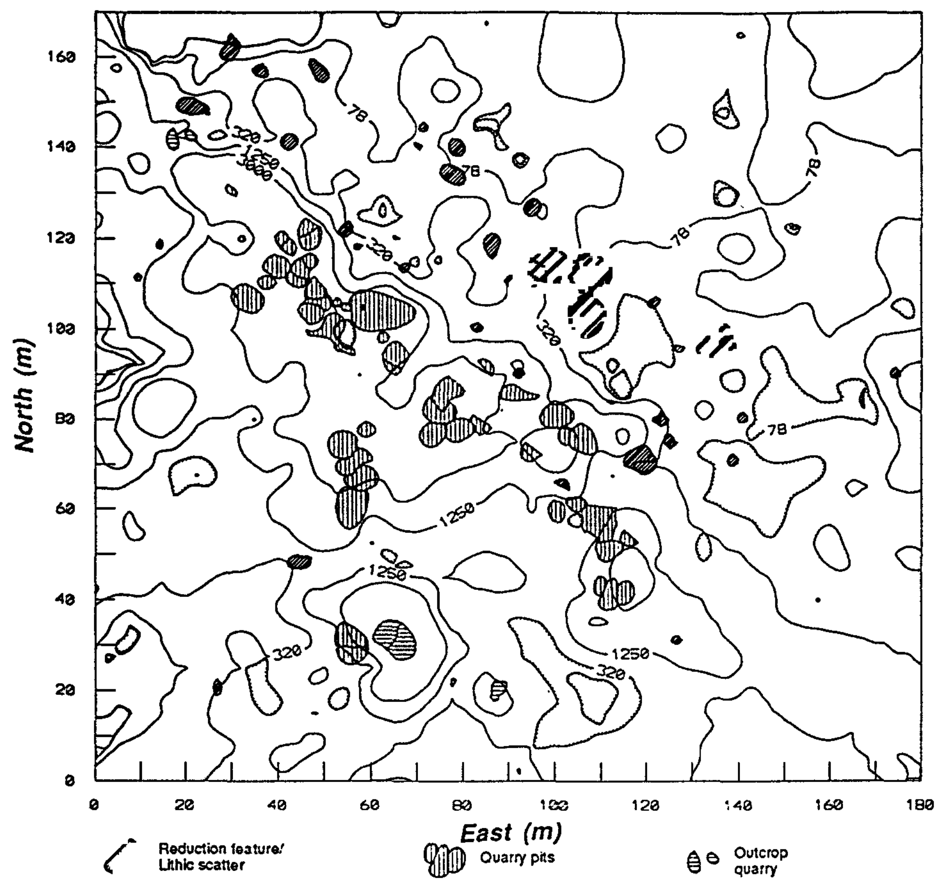


Figure 93. Isoline and wire-mesh plots of total flake frequency per square meter, based on 25 cm by 25 cm surface scrape data.



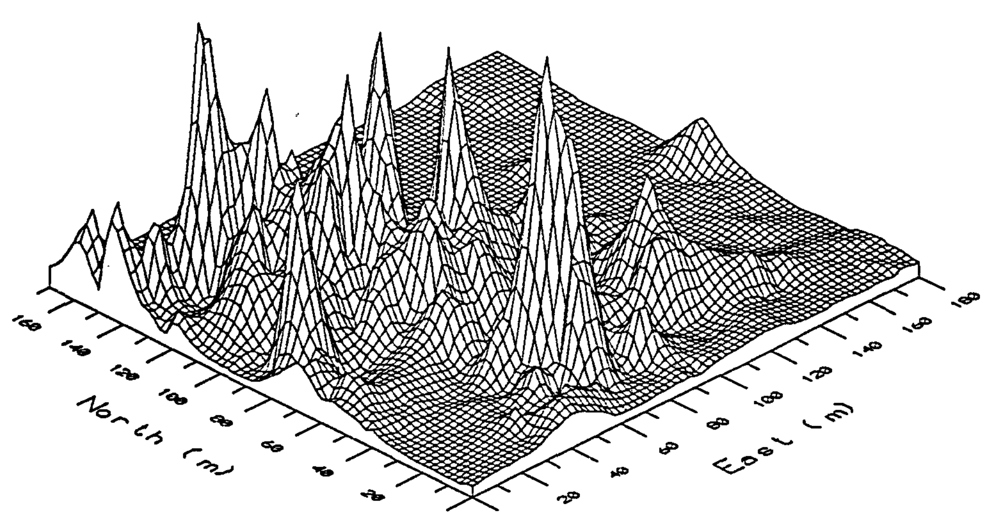


Figure 94. Isoline and wire-mesh plots of total flake weights per square meter, based on 25 cm by 25 cm surface scrape data.

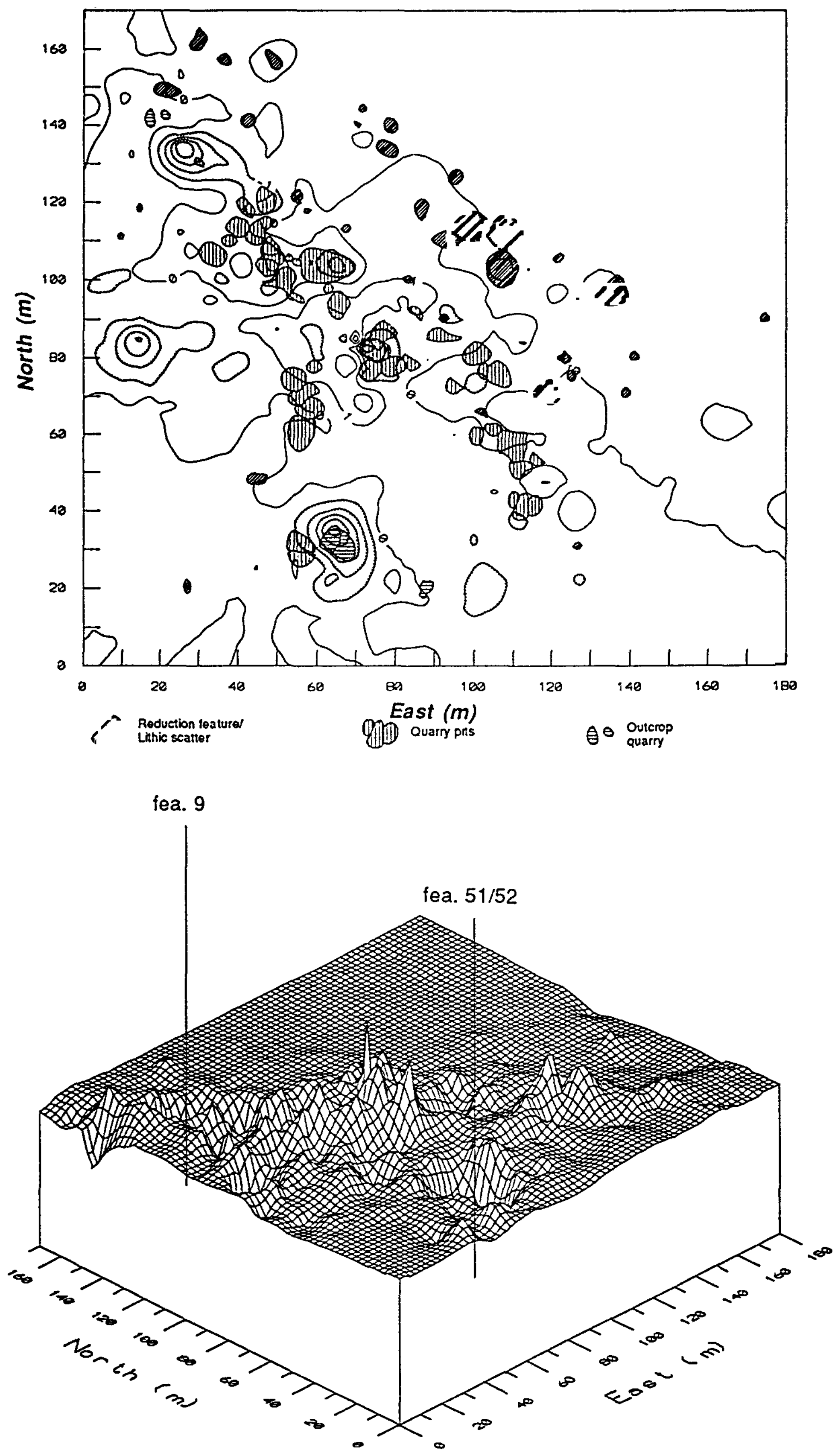


Figure 95. Isoline and wire-mesh plots of z-score values for total flake frequency minus z-score values for total flake weight, based on 25 cm by 25 cm surface scrape data.

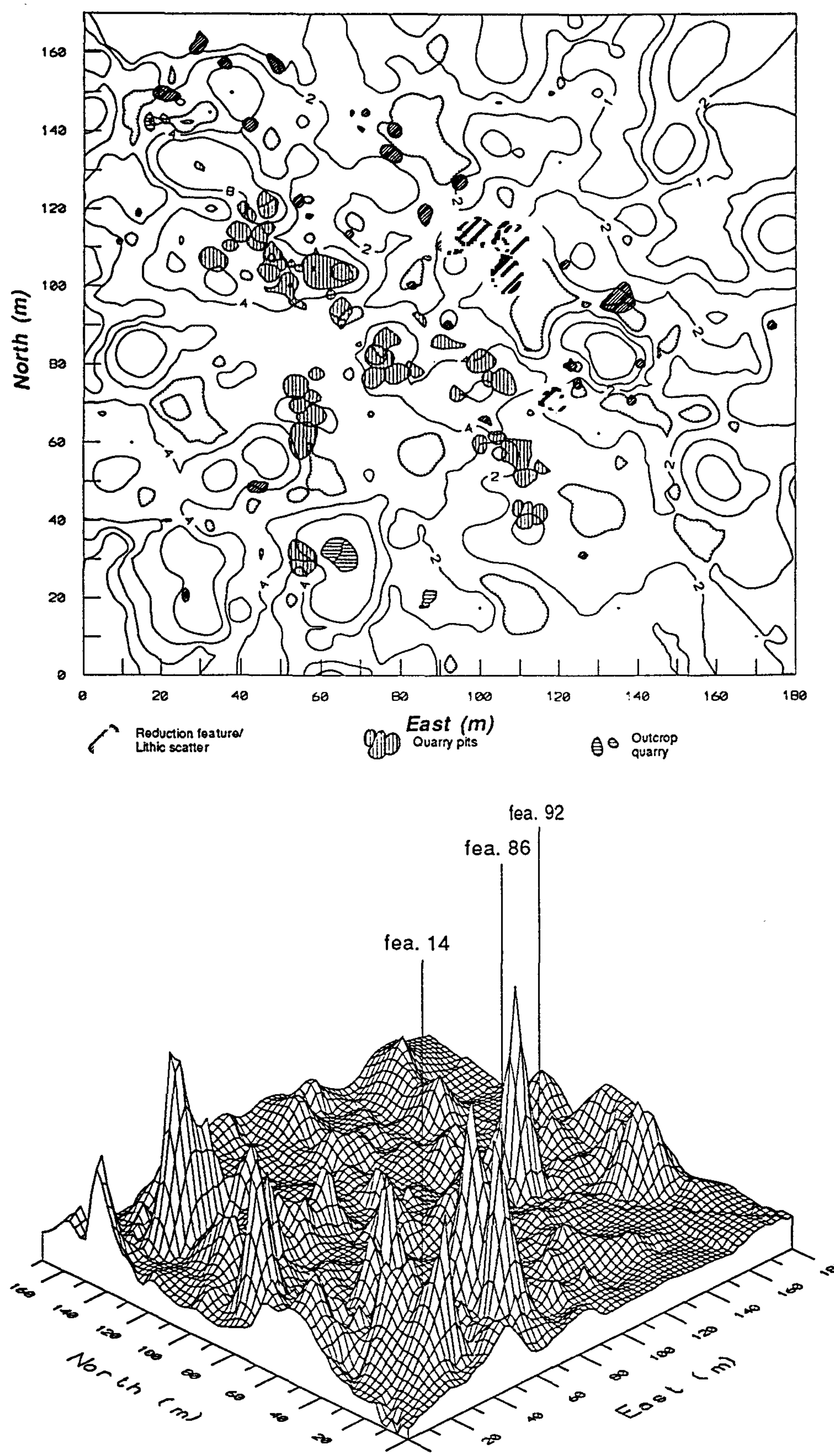


Figure 96. Isoline and wire-mesh plots of average flake weight, based on 25 cm by 25 cm surface scrape data.

several other parts of the site, notably around the main complexes of quarry pits (although not around Features 71 through 74), and near three reduction features/lithic scatters (Feature 14 in the southwest part of the site, and near Features 86 and 92 in the central eastern part of the site).

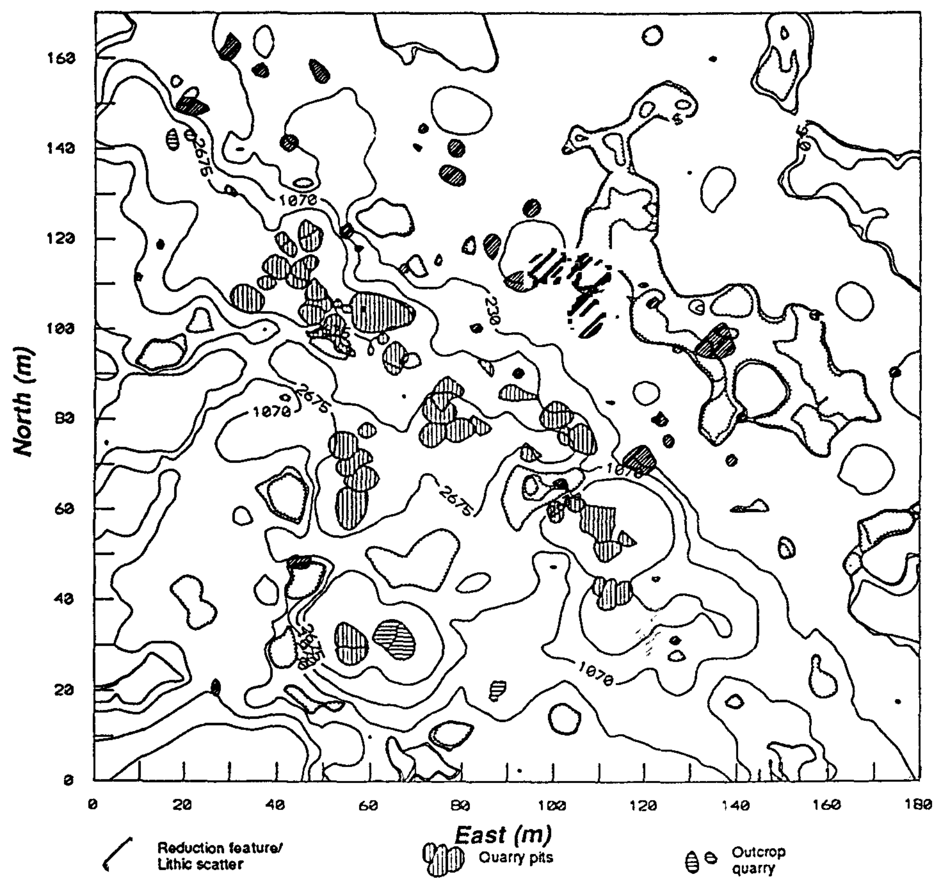
The utility of examining average flake weight extends beyond elucidating patterns. In principle, average flake weight should be greatest at the initiation of lithic reduction when large flakes are driven from cores. Average flake weight then should diminish through the reduction sequence, as ever thinner or smaller flakes are struck to shape a core or tool (Ingbar, Larson, and Bradley 1989). In practice, it is fairly easy to forecast some exceptions to this general proposition: intensive trampling of a debitage assemblage will increase the breakage frequency, causing average flake weight to decrease (Prentiss and Romanski 1989); so too, differential friability of raw material may cause flakes of one material to break more often than those of another, and cores of different sizes may produce flake assemblages of different average flake weights within the same reduction stages (cf. Chapter 4). Thus, the observed pattern may well reflect not only reduction, but numerous other factors. Sorting variation in flake size caused by lithic reduction actions from such other factors requires consideration of additional attributes of the debitage assemblage.

Areas of high average flake weights resulting from initial reduction of toolstone also should have high angular debris weights (Figure 97), since initial reduction produces primarily angular debris and large flakes. High average flake weight areas around Features 51 and 52, at the northern end of the main quarry pit complex, and in an area unassociated with known features centered on N80/E10, meet these criteria. Since Features 51 and 52 are opalite outcrops with associated lithic scatters, production of large flakes and much angular debris may reflect the extraction techniques used there (cf. Chapter 9). More generally, extraction and initial reduction of large pieces of stone (whether from pits or outcrops) may result in such values; perhaps this is the case for the area at the northern end of the main quarry pit complex around Feature 9. The area centered on N80/E10, on the other hand, lies in a swale downslope from the main quarry pit complexes. The high values for average flake weight and angular debris weight could be due to colluvial movement of material from above, if the debitage in this area is not in its original depositional locus. If it is in its original place of deposition, then perhaps smaller items were washed from it, leaving a lag deposit of large flakes and angular debris.

There also are areas having low to median values for mean flake weight and high weights of angular debris—around Features 78, 79, and 80, and west of Features 2 and 3 in the northwestern corner of the locality. These may be places where extraction debris or initial reduction of extracted blocks occurred without much further reduction; alternately, the toolstone extracted may not have been amenable to production of large flakes.

The converse pattern (high average flake weights and low to median total weights of angular debris) occurs as well. The area between Features 84 and 92, as well as the eastern margin of the site, exhibit this pattern. These may be areas in which little initial toolstone reduction took place. High average flake sizes may indicate later reduction of large pieces of opalite, or less post-depositional trampling. Insofar as angular debris weight reflects extraction or initial processing of toolstone, Figure 97 also shows that such actions have a close spatial association with toolstone sources.

Isoline plots for average flake weight and angular debris weight suggest that initial reduction of toolstone is spatially limited to areas close to quarry features. The ratio of total flake weight to total angular debris weight (Figure 98) exposes the relative proportions of each kind of debitage. In general, the western third of the site (west of almost all the quarry pits) has very little angular debris (cf. Figure 97); flakes (usually at least 25 times the weight of angular debris) dominate debitage aprons downslope of quarry pits. Near the major quarry pit complexes, and downslope (southwest) from them,



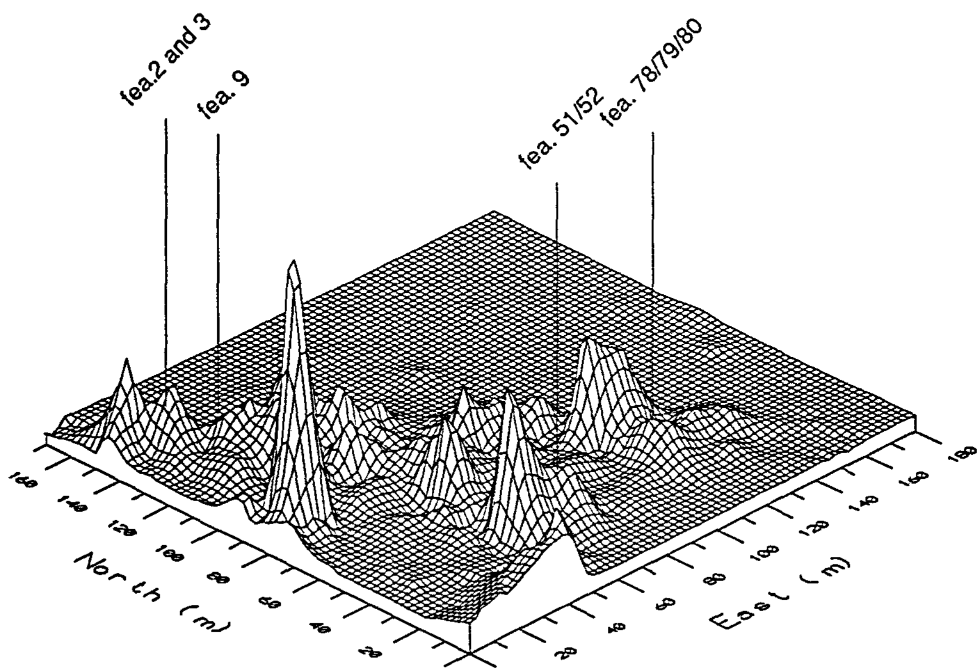


Figure 97. Isoline and wire-mesh plots of total angular debris weight per 25 cm by 25 cm area, based on 25 cm by 25 cm surface scrape data.

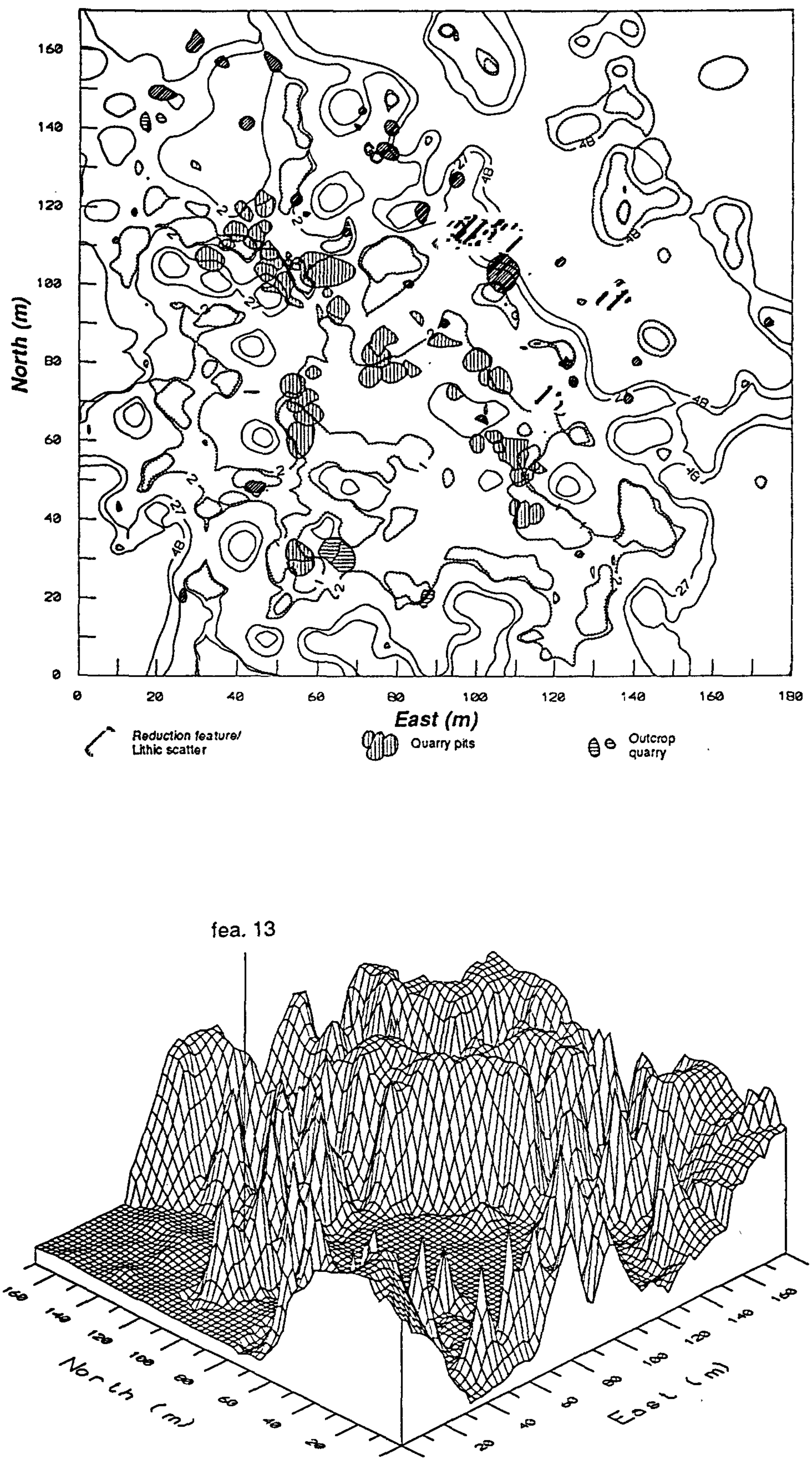


Figure 98. Isoline and wire-mesh plots of total flake weight divided by total angular debris weight, based on 25 cm by 25 cm surface scrape data.

the pattern is reversed: angular debris dominates. An interesting exception to this overall pattern is seen near Feature 13 in the west central part of the site, where an area of low angular debris weight (cf. Figure 97) contains a relatively high weight of flakes. This, perhaps, was an area where later reduction of toolstone occurred exclusively, but it is uncharacteristically close to the quarries.

This initial examination of debitage distribution, using several gross attributes of the samples, shows several interesting patterns. First, the spatial signature of debitage frequency clearly is tethered to quarry pit locations: debitage aprons appear as distinct, high frequency, high weight scatters of flakes and angular debris. Second, generalizations about the kind of reduction represented in debitage aprons may be risky: there are areas with little angular debris and many flakes, the converse, and broad scatters of flakes of different sizes. Third, the debitage attributes of areas away from the quarry and the quarry associated debitage aprons are not simple, although there is virtually no angular debris more than 10m east (upslope, in general) from quarry pits. For example, the area of larger flakes found in surface scrape units between Features 84 and 92 is unique away from the quarry pit. Thus, it is difficult to support a model of uniformity amongst reduction settings.

These results lead to further inquiry: is there a systematic relationship between the attributes used above and technological characterizations (cf. Chapter 4)? This was examined by undertaking technological analysis of 64 surface scrape unit debitage samples. Sample selection was entirely purposive, predicated on total flake weight and total flake count (Figure 99). A total flake weight of 420 g was used to divide the debitage assemblage into two groups of high and low weight. Samples then were selected from each of the two weight groups. Similarly, a count of 100 items (per 25x25 cm surface scrape unit) discriminated high and low count samples. The samples then were analyzed technologically using techniques discussed in Chapter 4.

Figure 100 shows the sample distribution across the locality on the isoline plot used to compare total counts and weights. The overall frequency of individual technological characterizations (Table 39) is similar to that found in the other technologically analyzed samples (cf. Table 9). However, when frequencies of individual technological characterizations are cross-tabulated by count and weight classes (Table 40) some simple patterns become evident. All samples contain quarrying and mass reduction debitage. Later stages of reduction, particularly blank preparation and early biface thinning, are more common in high count samples. Because the high count-high weight group contains only two samples, it probably should be excluded from consideration. Thus, later stages of reduction are most common in the high count-low weight group. High count-low weight samples are, of course, those with the lowest average flake weights. Therefore, the analytical results support the model posed above in which lower average flake weights were posited to indicate later stages of reduction. This analysis cannot be extended to numerous surface scrape samples due to the small numbers of flakes recovered from them.

Table 39. Frequency of Single Characterizations,
25x25 cm Surface Scrape Debitage Samples (n=64).

Category	n	% of total
Q	53	82.8
M	63	98.4
B	30	46.9
E	17	26.6
L	6	9.4

Key: Q = quarrying; M = mass reduction; B = blank preparation; E = early biface thinning; L = late biface thinning

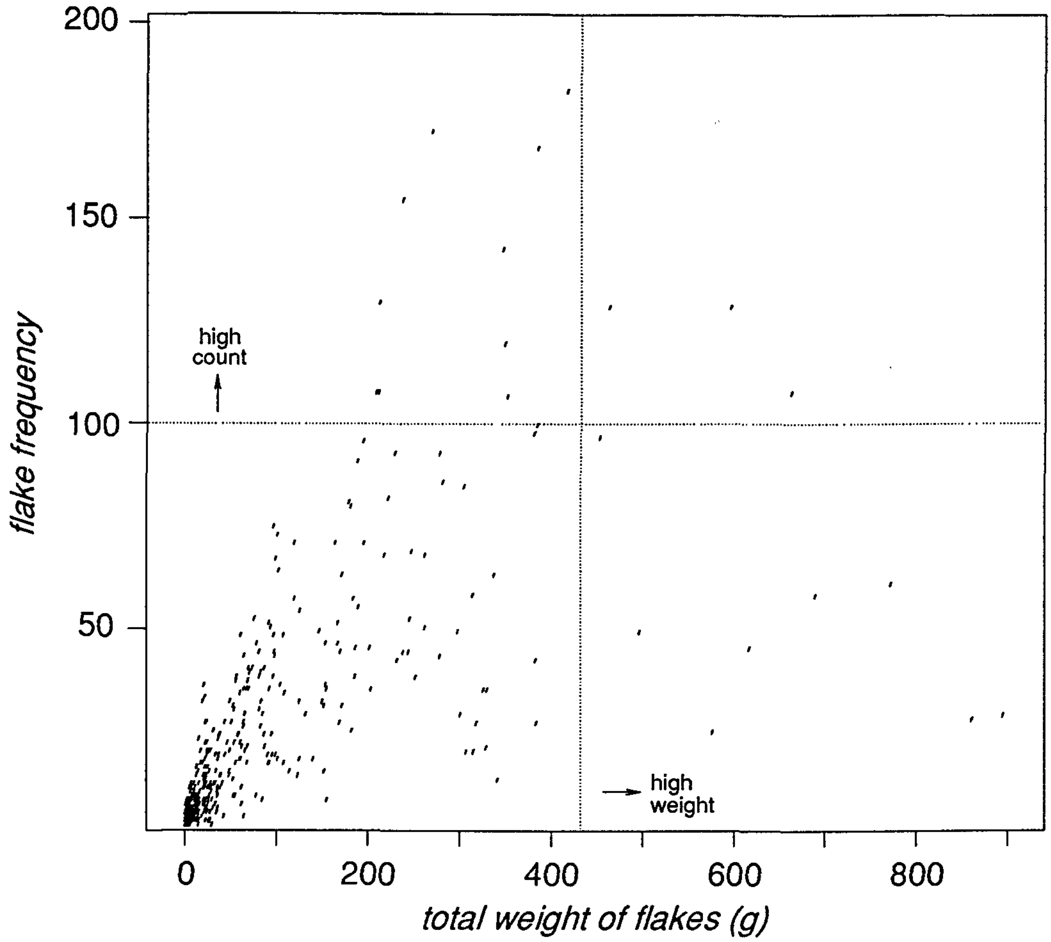


Figure 99. Scatter plot of flake frequency vs. flake weight for all 25 cm by 25 cm surface scrape debitage samples.

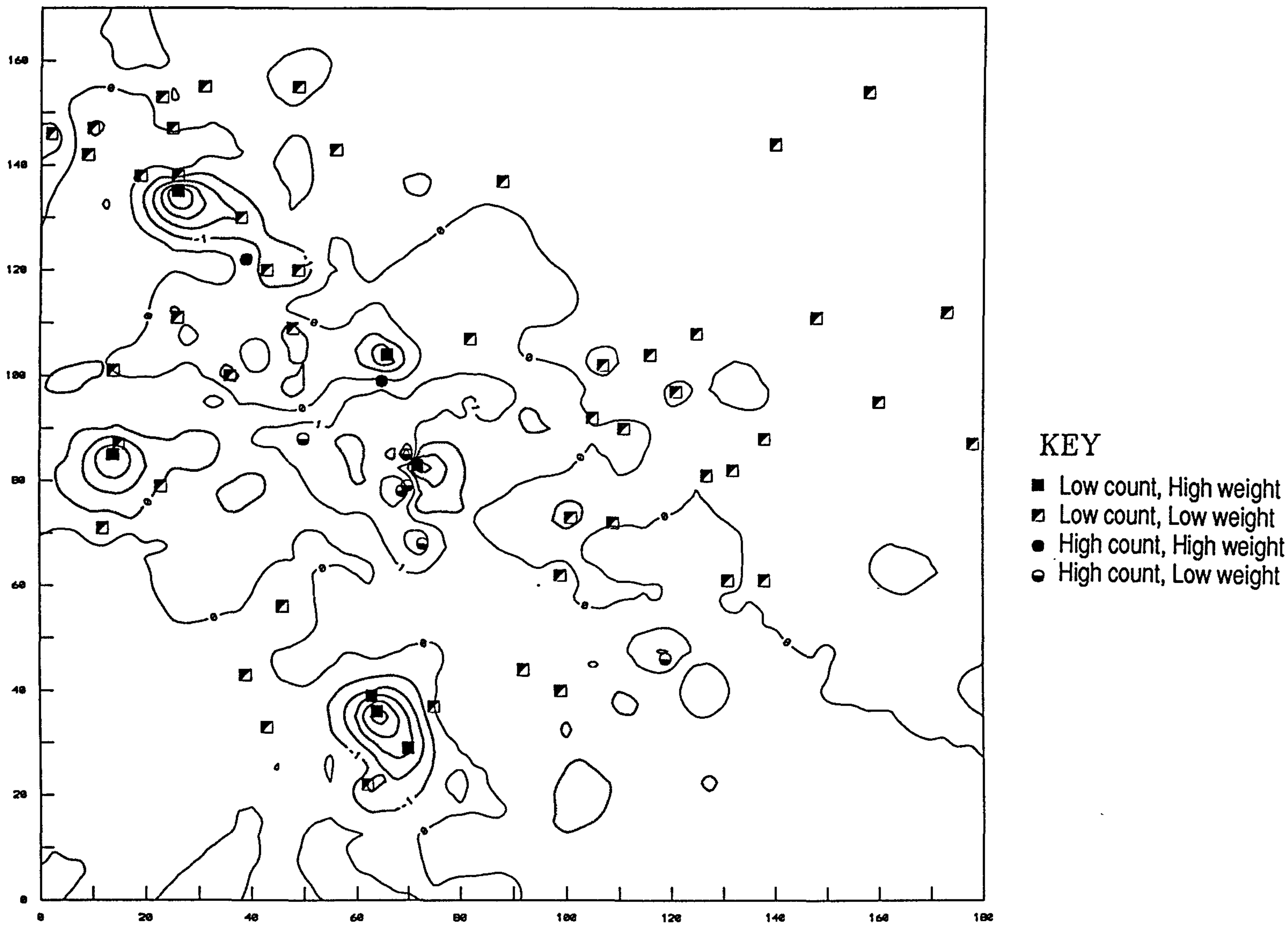


Figure 100. Distribution of technologically analyzed 25 cm by 25 cm surface scrape samples.

Table 40. Frequency of Single Characterizations Cross-tabulated by Count and Weight Groupings, 25x25 cm Surface Scrape Debitage Samples.

	HIGH COUNT				LOW COUNT			
	High Weight (n=2)		Low Weight (n=6)		High Weight (n=7)		Low Weight (n=49)	
Category	n	%	n	%	n	%	n	%
Q	2	100.0	6	100.0	7	100.0	38	77.6
M	2	100.0	6	100.0	7	100.0	48	98.0
B	2	100.0	5	83.3	4	57.1	19	38.8
E	2	100.0	4	66.7	1	14.3	10	20.4
L	1	50.0	1	16.7	0	0.0	4	8.2

Key: Q = quarrying; M = mass reduction; B = blank preparation; E = early biface thinning;
L = late biface thinning

Technological Variation in Debitage

Here we compare the debitage from different feature settings to determine whether there is an association between lithic reduction actions and any particular feature classes. This was discussed in passing in Chapter 4, where the technological analysis of quarry pit debitage samples was contrasted with results from other Tosawihi quarry sites. Results of technological analyses from different feature contexts *within* the locality are compared here.

The samples used for this analysis are the 319 samples discussed in Chapter 4. The frequencies of individual technological characterizations, following the conventions used already, were tabulated for each feature context. However, trace amounts of a particular characterization were grouped with absent, and the dominant and frequent characterizations were summed (Table 41). For each contrast, a contingency table was made, comparing the frequencies of characterizations between the two feature contexts (e.g., quarry pits vs. reduction features, quarry pits vs. all non-quarry settings). Chi-square then was calculated. If this was statistically significant at a confidence level of $p=0.05$, adjusted standardized residuals (Everitt 1977, Grayson 1984) were derived to explore the direction of difference and permit interpretation. This use of chi-square is not intended to serve as a test of hypotheses; rather, it is a technique for elucidating pattern. Results are presented in Table 42.

Table 41. Frequencies of Technological Analysis Single Categorizations by Context.

Technological Characterization	Quarry Pit/ Quarry Area	Reduction Feature	Hearth/ Possible Hearth	Non-Feature	Feature 102[1]
Q* or Q	103	2	0	54	30
q or none	19	112	18	11	5
M* or M	107	49	7	64	32
m or none	15	65	11	1	3
B* or B	59	90	14	31	17
b or none	63	24	4	34	18
E* or E	61	85	14	17	14
e or none	61	29	4	48	21
L* or L	3	13	0	6	0
l or none	119	101	18	59	35

[1]Already included in frequencies listed for quarry pit/quarry area samples.

Key:

Q = quarrying
M = mass reduction
B = blank preparation
E = early biface thinning
L = late biface thinning

Lower case: Trace Quantity
Upper case: Frequent
Upper case w/asterisk: Dominant

Table 42. Summary of Results for Contingency Table Contrasts of Individual Technological Analysis Characterizations by Feature Contexts.

Presence/Absence of Technological Characterization	Quarry Pit/ Quarry Area to Reduction Features	Quarry Pit/ Quarry Area to Non-Feature Area	Reduction Features to Non-Feature Area	Reduction Features to Hearths and Possible Hearths	Quarry Pit/ Quarry Area to Feature 102
Quarry debris	more in quarry areas	no significant difference	more in non-feature area	no significant difference	no significant difference
Mass reduction	more in quarry areas	more in non-feature areas	more in non-feature areas	no significant difference	no significant difference
Blank preparation	more in reduction features	no significant difference	more in reduction features	no significant difference	no significant difference
Early biface thinning	more in reduction features	more in quarry areas	more in reduction features	no significant difference	no significant difference
Late biface thinning	more in reduction features	more in non-feature areas	no significant difference	more in hearth areas	no significant difference

Compared to reduction features, quarry pit and quarry area debitage samples have more early reduction (quarrying debris from extraction of opalite and mass reduction flakes struck to shape a core; cf. Chapter 4) and less later reduction (blank preparation, early and late biface thinning). When quarry pit and quarry area debitage samples are compared to those from non-feature contexts (collections made from excavation units having no feature associations), non-feature settings have more mass reduction and late biface thinning debitage (although we observed few specimens of the latter). Quarry pit and quarry area samples have more early biface thinning than do non-feature samples. Relative to reduction features, however, the non-feature samples are technologically earlier. In sum, samples from three general contexts (quarry pit, reduction feature, and non-feature area) show that quarry features exhibit earlier stage reduction than reduction features, non-feature samples are technologically intermediate between the two other settings, and the major differences between quarry debitage samples and non-feature debitage samples are that the latter have disproportionately high frequencies of mass reduction and low frequencies of early biface thinning. This suggests that the non-feature debitage samples reflect an entirely different suite of technological behaviors: they seem both later (having more mass reduction) and earlier (having significantly less early biface thinning) than quarry samples.

The results may indicate the spatial extent of different technological actions. Quarrying debris clearly is limited to the surroundings of bedrock sources, as both this analysis and the general debitage distribution analyses demonstrate. Blank preparation and early biface thinning also are somewhat spatially restricted, evident mostly in accumulations of debitage. We defined such accumulations as features (either reduction feature/lithic scatters or quarry pits). Once the activities forming such features began, or had occurred in a place before, they tended to recur in the same portion of site space. Mass reduction debitage, the hallmark of non-feature samples, is not so restricted in its spatial occurrence; in fact, it occurs most frequently outside organized reduction or quarry features. So, different technological actions may have similar spatial extents. Early biface thinning may be restricted spatially, depositing debris in only a small radius. Quarrying is more spatially extensive, and mass reduction more extensive still. These spatial extents can overlap, and only through analysis of technological attributes can they be isolated.

We undertook comparison of the debitage assemblages from hearths and possible hearths with those from reduction features/lithic scatters, although the number of interpretable samples from hearth settings is low (cf. Table 41). The sole difference between these two contexts, technologically, is a higher than expected frequency of late stage thinning in hearths.

We made another technological comparison, between Feature 102, a buried quarry feature dating to approximately 4000 yrs. B.P. (cf. Chapter 8), and all other quarry pit debitage assemblages. Feature 102 debitage samples had a higher frequency of early biface thinning than any other quarry pit samples. However, in terms of single occurrences of technological categories, the two sample sets do not differ. This does not contradict the observation made during the debitage analysis, but it does indicate that the simple comparison of category *incidence* does not reflect frequency variation within a category.

Distribution of Distinctive Raw Materials

Most opalite from Locality 36 bedrock is indistinguishable, but one distinctive variety with swirled bands was the target of quarrying at Feature 102, a buried quarry pit. (Other distinctive raw material characteristics, such as variations in trace element composition, may occur at Locality 36, but we made no special effort to identify them.) This feature provided the oldest radiocarbon age from the locality and, since its raw material was distinguishable, we tallied its presence in all debitage samples and bifaces. Figure 101 shows the distribution of "swirled" opalite debitage, Figure 102, the distribution of "swirled" opalite bifaces.

Swirled opalite debitage is infrequent, being present in low quantities (5 to 10 pieces of debitage per occurrence) in four of the six features where it appears (reduction features/lithic scatter Features 63, 87, 92, and hearth feature Feature 105). It is very common, however, in Features 49 and 102, which are at the source of the material. Swirled opalite bifaces also are most frequent in the two features at the material source. They are present in low frequencies (1 or 2 bifaces per feature) in Features 18, 19, 28, 48, 50, 63.

Swirled opalite may have been used only while Feature 102 was an active quarry (cf. Chapter 9). However, a few flakes of swirled opalite are associated with Feature 105, which was radiocarbon dated to 330±50. The later use of swirled opalite may owe to scavenging of previously quarried stone or from additional exposures of the stone in Feature 49, which is younger than Feature 102.

Stone Tool Distributions

The most frequent classes of stone tools at Locality 36 are bifaces and hammerstones. Distributional analyses of these are discussed below. Ground stone, projectile points, and flake tools are so infrequent that their distributions are uninformative and are not discussed. Modified chunks are frequent and are found predominantly in quarry pits (cf. Chapter 5).

The distributions of hammerstones and bifaces were examined in a fashion similar to that used in analysis of debitage distributions. Hammerstones (cf. Chapter 6) are useful for distributional analysis not only because they are relatively common, but also because they are related directly to opalite extraction and subsequent reduction into transportable forms. The distribution of bifaces was investigated because bifaces were the major product derived from Locality 36 by prehistoric flintknappers (cf. Chapter 5).

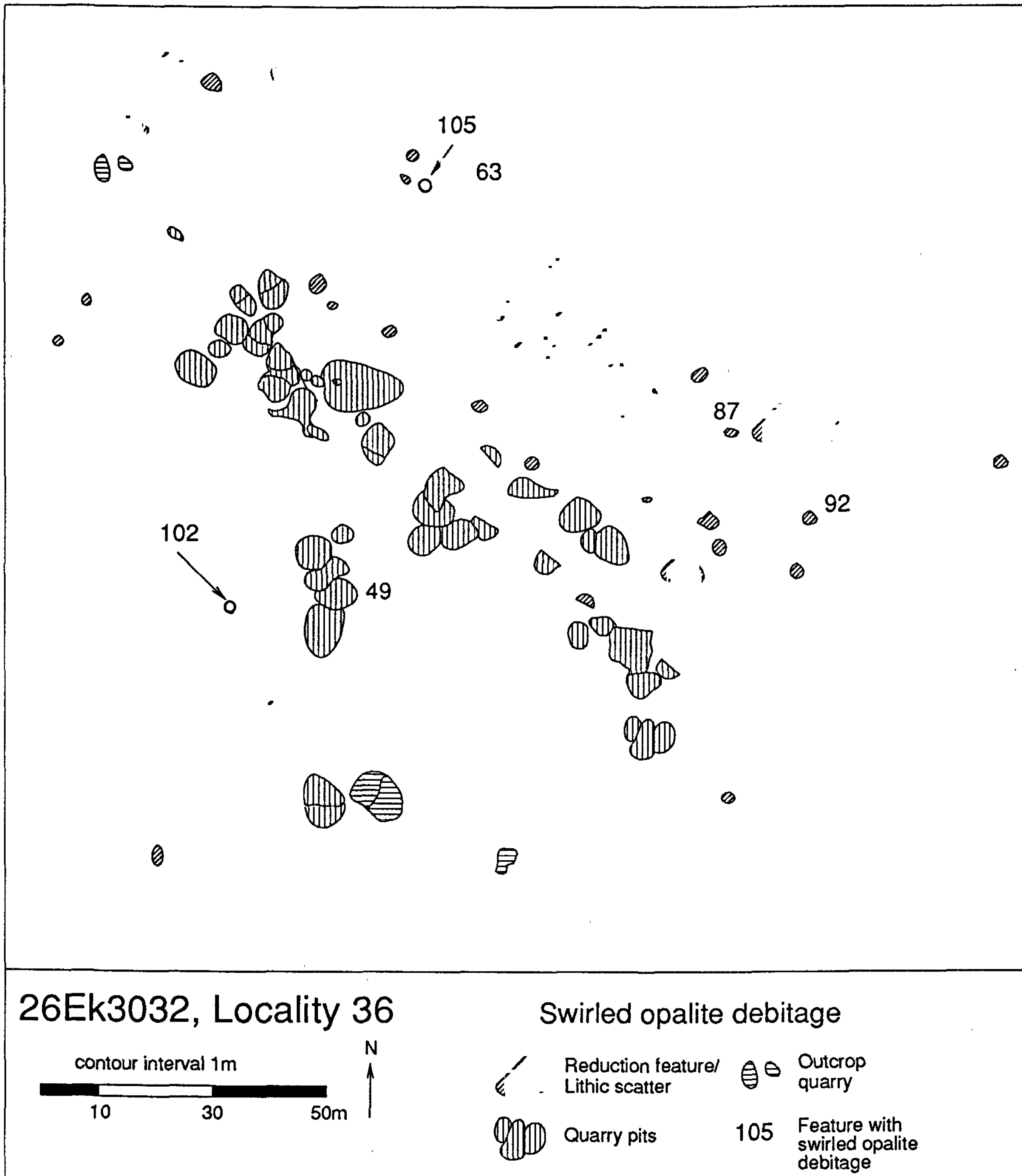


Figure 101. Distribution of "swirled" opalite debitage.

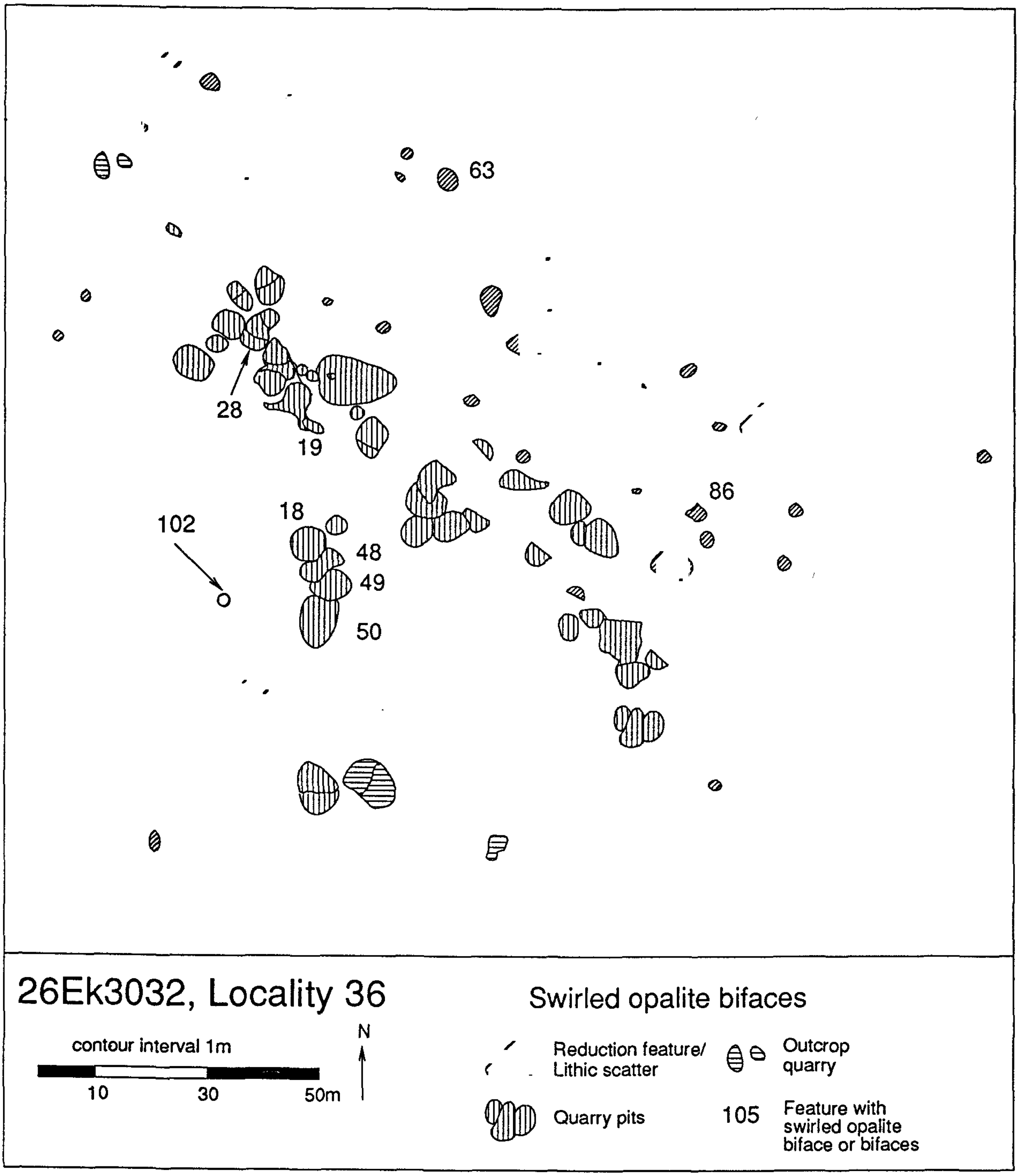


Figure 102. Distribution of "swirled" opalite bifaces.

Hammerstone Distributions

Three attributes of the hammerstone assemblage were examined: hammerstone weight (i.e., size, since most raw materials are of similar density), raw material source, and completeness. Data used for the analysis are derived from those in Chapter 6.

If quarrying required the heaviest hammerstones, then unbroken hammerstones from quarry pits should have weights significantly higher than those from other settings. A t-test of the 78 complete hammerstone weights, grouped by quarry pit vs. all other contexts, shows that this was not the case (t=0.148, p=0.88; $n_{\text{quarry pit}}$=67, mean=965.5 g, std. dev.=852.0 g; $n_{\text{non-quarry pit}}$=11, mean=1005.4 g, std. dev.=822.8 g).

If raw material properties differ in their suitability for hammers, we might expect the toughest to have been used for quarrying since that is the heaviest work. In general, the local raw material used for hammerstones (opalite and tuff) is less durable (being only as hard as the opalite itself) than non-local raw materials (especially quartzite, but also basalt, rhyolite, and other stone). So, comparing local and non-local raw materials contrasts hammerstone durability, as well as raw material selectivity. Raw material and feature context were found to be dependent (Table 43). The hammerstone assemblage from quarry pits exhibits a higher than expected frequency of local raw materials and lower than expected frequency of non-local raw materials. The converse is true for the non-quarry pit hammerstone assemblage. The extensive use of local, perhaps less durable, material within quarry pits may owe to its proximity, since virtually every quarry pit has an endless supply of opalite or tuff hammers. Given their ready availability, opalite and tuff hammerstones simply may have been discarded when no longer needed. Hammerstones of non-local material also were used within quarry pits; a few basalt or quartzite hammerstone flakes usually occur in every quarry pit debitage sample, but being both more durable and less available, hammers of these materials were used in actions outside the quarry pits too. Discard may have occurred at their place of use, as well.

Table 43. Contingency Table of Hammerstone Raw Material (local vs. nonlocal) by Feature Context (quarry pit vs. non-quarry pit).

	RAW MATERIAL SOURCE	
Feature Context	Local	Nonlocal
Quarry pits	31 (2.39*)	89 (-2.39*)
Not quarry pits	1 (-2.39*)	24 (2.39*)

chi-square = 5.73; df=1, p<0.05
(adjusted standardized residual, asterisk indicates p<0.05)

If hammerstones had different durations of use, as suggested above, then one might expect that local and nonlocal hammerstones would have been discarded in different states of completeness. Table 44 shows this expectation to be correct. Hammerstones of local raw material are more often complete (and less often broken) than non-local ones. Despite the association of complete hammerstones made of local raw material with quarry pits, there is no statistically significant association between feature context and frequency of complete hammerstones.

Table 44. Contingency Table of Hammerstone Raw Material (local vs. nonlocal) by Hammerstone Completeness.

Completeness	RAW MATERIAL SOURCE Local	Nonlocal
Complete	28 (4.33*)	50 (-4.33*)
Incomplete	4 (-4.33*)	63 (4.33*)

chi-square = 5.73; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

The distribution of hammerstones suggests that local raw materials may have been used for quarrying and only slightly for later reduction. Opalite and tuff hammerstones probably were used expediently and discarded. Hammerstones of nonlocal materials *may* have been used in quarrying, but their ultimate discard location was determined more by their utility in later stages of opalite reduction. Hence, they tend to be found broken in non-quarry pit contexts.

Biface Distributions

Bifaces are the dominant stone tool class in the flaked stone assemblage. There can be little doubt that biface production was an important aspect of prehistoric use of the opalite sources at Locality 36. As previously discussed, the Locality 36 biface is highly patterned: heat-treatment is significantly more common among mid-Stage 3 and later specimens, and early stage (Stages 1 and 2) bifaces are broken less often than those in or later than mid-Stage 3 (cf. Chapter 5). The distribution of bifaces provides information on where bifaces were discarded (and probably manufactured). Such information reflects the spatial organization of biface production.

Bifaces are most common in quarry pits followed by non-feature settings, then reduction features/lithic scatters (Table 45). In general, discard of bifaces occurred twice as often in quarry pit contexts than in all other feature types. If bifaces always were discarded at the locus of their failure in manufacture, then biface failure was more frequent in the quarry area than elsewhere. Sizes and failure causes of bifaces from the quarry area (cf. Chapter 5) support this. The pattern of robust association between reduction features and biface reduction debitage is due to the dominance of biface reduction in reduction features, whereas quarry pits have more technologically heterogeneous debitage assemblages. Considered together, the two results suggest that many bifaces failed in the quarry area, and some undetermined number were reduced successfully away from the quarry pits, leaving behind a lithic scatter dominated by biface reduction debris.

Table 45. Overall Frequency, Proportions, and Average Number of Bifaces per Feature Type.

Feature Type	Feature Frequency	Biface Frequency	Percent of Biface Assemblage	Average No. of Bifaces per Feature
Quarry pits	60*	381	60.0	6.4
Reduction features	37	102	16.1	2.8
Hearths/possible hearths	5	8	1.3	1.6
Outcrop quarries	5	12	1.9	2.4
Non-feature area	--	132	20.8	--

* includes subsurface quarry features

Further elucidation of spatial patterns of biface discard can be found in the relationship between biface reduction stage and feature type (Table 46). Table 47 summarizes chi-square contrasts (at p=0.05) and analysis of adjusted standardized residuals of various attributes of the biface assemblage vs. spatial contexts. Since all the analyses summarized in Table 47 can be derived from the data presented in Table 46, intervening contingency tables are not presented.

Table 46. Cross-tabulation of Frequency of Biface Reduction Stage by Feature Type.

Biface Reduction Stage	FEATURE CONTEXT Quarry Pit	Reduction Feature	Hearth/ Possible Hearth	Outcrop Quarry	Non-feature
Stage 1	2	1	0	0	0
Early Stage 2	25	5	0	0	1
Mid-Stage 2	73	15	1	0	10
Early Stage 3	220	51	4	5	63
Mid-Stage 3	47	20	2	5	33
Late Stage 3	4	3	0	1	17
Stage 4	1	2	0	1	2
Stage 5	0	0	0	0	2
Indeterminate	9	5	1	0	4

Table 47. Summary of Contingency Table Comparisons Between Biface Stages and Different Feature Contexts.

Biface Stages Contrasted	**Quarry Pits to Reduction Features**	**Quarry Pits to All Non-quarry Pit Contexts**	**Non-feature Area to Reduction Features**	**Non-feature Area to Quarry pits**
Early (Stages 1 to mid-Stage 2) to Late (mid-Stage 3 to Stage 5)	Quarry pits associated with early, reduction features with late	Quarry pits associated with early, non-quarry contexts with late	Non-feature area associated with late, reduction features with early	Non-feature area associated with late, quarry pits with early
Stage 2 to early Stage 3	No association	No association	Non-feature area associated with Stage 3, reduction features with Stage 2	Non-feature associated with Stage 3, quarry pits with Stage 2

The distribution of early stage (up to but not including Stage 3) vs. late stage (mid-Stage 3 and later) bifaces across feature contexts is not random (Table 47). Early stage bifaces are associated strongly with quarry pits, later stage bifaces with reduction features/lithic scatters and non-quarry pit settings generally. Early Stage 3 bifaces, in the middle of the reduction continuum, do not differ in association from Stage 2 bifaces (Table 47) between quarry pits and all other contexts.

Bifaces not associated with features are generally later in stage than those from quarry pits and reduction features/lithic scatters (Table 47). Bifaces from feature and non-feature settings also differ in the Stage 2 to early Stage 3 comparison, where once again non-feature bifaces are later in reduction stage than bifaces from reduction feature/lithic scatters. Debitage contrasts between reduction feature/lithic scatters and the non-feature areas exhibit a different pattern, with earlier (mass reduction) debitage associated with non-feature contexts and later (biface reduction) debitage associated with reduction feature/lithic scatters.

Heat-treatment and brokenness are associated strongly with the later stages of biface reduction within the overall assemblage (cf. Chapter 5). These attributes have significant associations with feature contexts (Tables 48 to 51). Bifaces in quarry pits are more often complete and not heat-treated than those from non-quarry pit contexts or reduction features only. Thus, early and late biface reduction and associated attributes of heat-treatment and completeness all pattern across feature contexts.

Table 48. Contingency Table of Feature Context (quarry pit vs. reduction feature) by Heat-treatment, Biface Assemblage.

	FEATURE CONTEXT	
Heat-Treatment	Quarry Pits	Reduction Features
Heat-treated	5 (-2.32*)	5 (2.32*)
Not heat-treated	376 (2.32*)	94 (-2.32*)

chi-square = 5.38; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Table 49. Contingency Table of Feature Context (quarry pit vs. non-quarry pit) by Heat-treatment, Biface Assemblage.

	FEATURE CONTEXT	
Heat-Treatment	Quarry Pits	Not Quarry Pits
Heat-treated	5 (-5.40*)	28 (5.40*)
Not heat-treated	376 (5.40*)	226 (-5.40*)

chi-square = 29.17; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Table 50. Contingency Table of Feature Context (quarry pit vs. reduction feature) by Completeness, Biface Assemblage.

	FEATURE CONTEXT	
Completeness	Quarry Pits	Reduction Features
Complete	202 (3.18*)	36 (-3.18*)
Incomplete	179 (-3.18*)	66 (3.18*)

chi-square = 10.11; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Table 51. Contingency Table of Feature Context (quarry pit vs. non-quarry pit) by Completeness, Biface Assemblage.

	FEATURE CONTEXT	
Completeness	Quarry Pits	Not Quarry Pits
Complete	202 (3.28*)	101 (-3.28*)
Incomplete	179 (-3.28*)	153 (3.28*)

chi-square = 10.73; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Two attributes indicative of biface production technique merit consideration (cf. Chapters 4 and 5): initial core form (block or flake blank) and use of specialized techniques (end-thinning, thinning from square edges). As discussed in Chapter 5, initial core form usually can be identified only on early stage bifaces. Hence, Tables 52 and 53 tabulate the presence of one form vs. presence of another, rather than presence and absence. Block cores are more common than expected in quarry pits, flake blanks more common in reduction feature/lithic scatter and non-quarry pit contexts (Table 52, Table 53). Thinning from square edges and end-thinning are not associated with any particular feature context (Table 54, Table 55).

Table 52. Contingency Table of Feature Context (quarry pit vs. reduction feature) by Biface Blank Type, Biface Assemblage.

	FEATURE CONTEXT	
Blank Type	Quarry Pits	Reduction Features
Flake blank	55 (-1.98*)	17 (1.98*)
Block blank	34 (1.98*)	3 (-1.98*)

chi-square = 3.92; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Table 53. Contingency Table of Feature Context (quarry pit vs. non-quarry pit) by Biface Blank Type, Biface Assemblage.

	FEATURE CONTEXT	
Blank Type	Quarry Pits	Not Quarry Pits
Flake blank	55 (-1.98*)	34 (1.98*)
Block blank	34 (1.98*)	9 (-1.98*)

chi-square = 3.94; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Table 54. Contingency Table of Feature Context (quarry pit vs. reduction feature) by Specialized Thinning Techniques, Biface Assemblage.

	FEATURE CONTEXT	
Thinning Technique	Quarry Pits	Reduction Features
Square edge thinning	61 (0.37)	16 (-0.37)
End thinning	22 (-0.37)	7 (0.37)

chi-square = 0.14; df=1, $p>0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Table 55. Contingency Table of Feature Context (quarry pit vs. non-quarry pit) by Specialized Thinning Techniques, Biface Assemblage.

	FEATURE CONTEXT	
Thinning Technique	Quarry Pits	Not Quarry Pits
Square edge thinning	61 (0.63)	37 (-0.63)
End thinning	22 (-0.63)	17 (0.63)

chi-square = 0.40; df=1, $p>0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Feature 102, the oldest quarry feature known at Locality 36, has a higher frequency of late stage bifaces than other quarry pits (Table 56). In fact, there is no significant difference in biface stage frequency when the Feature 102 biface assemblage is compared to that from reduction features/lithic scatters (Table 57). No other quarry pit feature exhibits this pattern. In terms of early and late stage biface presence, Feature 102 is therefore more similar to reduction feature/lithic scatter biface assemblages than to other quarry pits.

Table 56. Contingency Table of Feature Context (Feature 102 vs. all other quarry pits) by Early and Late Stage Biface Stage Frequency.

	FEATURE CONTEXT	
Biface Reduction Stage	Feature 102	Other Quarry Pits
Early (Stages 1 to mid-2)	9 (-2.93*)	91 (2.93*)
Late (mid-Stage 3 to 5)	14 (2.93*)	38 (-2.93*)

chi-square = 8.56; df=1, $p<0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Table 57. Contingency Table of Feature Context (Feature 102 vs. reduction features) by Early and Late Stage Biface Stage Frequency.

	FEATURE CONTEXT	
Biface Reduction Stage	Feature 102	Reduction Features
Early (Stages 1 to mid-2)	9	21
	(-0.52)	(0.52)
Late (mid-Stage 3 to 5)	14	25
	(0.52)	(-0.52)

chi-square = 0.27; df=1, $p>0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

The distribution of bifaces centers on quarry pit complexes (Figure 103). The distance from each staged biface outside quarry pits to the nearest quarry pit is one way to measure biface distribution. The means and standard deviations of these distances, by reduction stage, are plotted in Figure 104. Stage 4 bifaces are somewhat farther from quarry pits than earlier stages, but there is no significant difference among the distances to quarry pits for reduction stages.

Summarizing the distribution of bifaces is relatively simple because the patterns are so strong. Bifaces from reduction feature/lithic scatters are generally later in reduction stage than those from quarry pits, with the exception of Feature 102. Bifaces from non-feature contexts are later still. Heat-treatment and completeness share these associations, as expected given their mutual dependence on reduction stage (cf. Chapter 5). The difference found in flake blank-based bifaces (generally more frequent in non-quarry pit settings) and block-based bifaces (more frequent in quarry pits) probably reflects a real difference in reduction technique. The spatial distribution of bifaces, like that of debitage, is centered on quarry features.

Spatial segregation of biface discard, and thus perhaps of biface production, is not apparent at Locality 36. Yet, the absence or invisibility of discrete work areas near the quarry pits cannot be taken to mean that biface production was not organized into discrete spatial areas. The observed distribution of bifaces is the result of over 4000 years of biface production, whether continuous or not. During any *single* use of the locality, biface production may have been removed spatially from active quarry features. Over time, with re-use of the site surface, these differences became indistinguishable as quarrying shifted from one feature to another.

Spatial Variation in Assemblage Contents

Earlier a distinction was drawn between three complexes of quarry pits: Area A, centered around Feature 71, Area B, centered around Feature 42, and Area C, centered around Feature 49 (cf. Chapter 8). Each area was defined using the boundaries shown in Figure 105 to evaluate differences in their content. Attributes of the bifaces and hammerstones from each feature group were tallied, as were the frequencies of single technological characterizations of debitage samples from them. These data then were used to look for differences between areas.

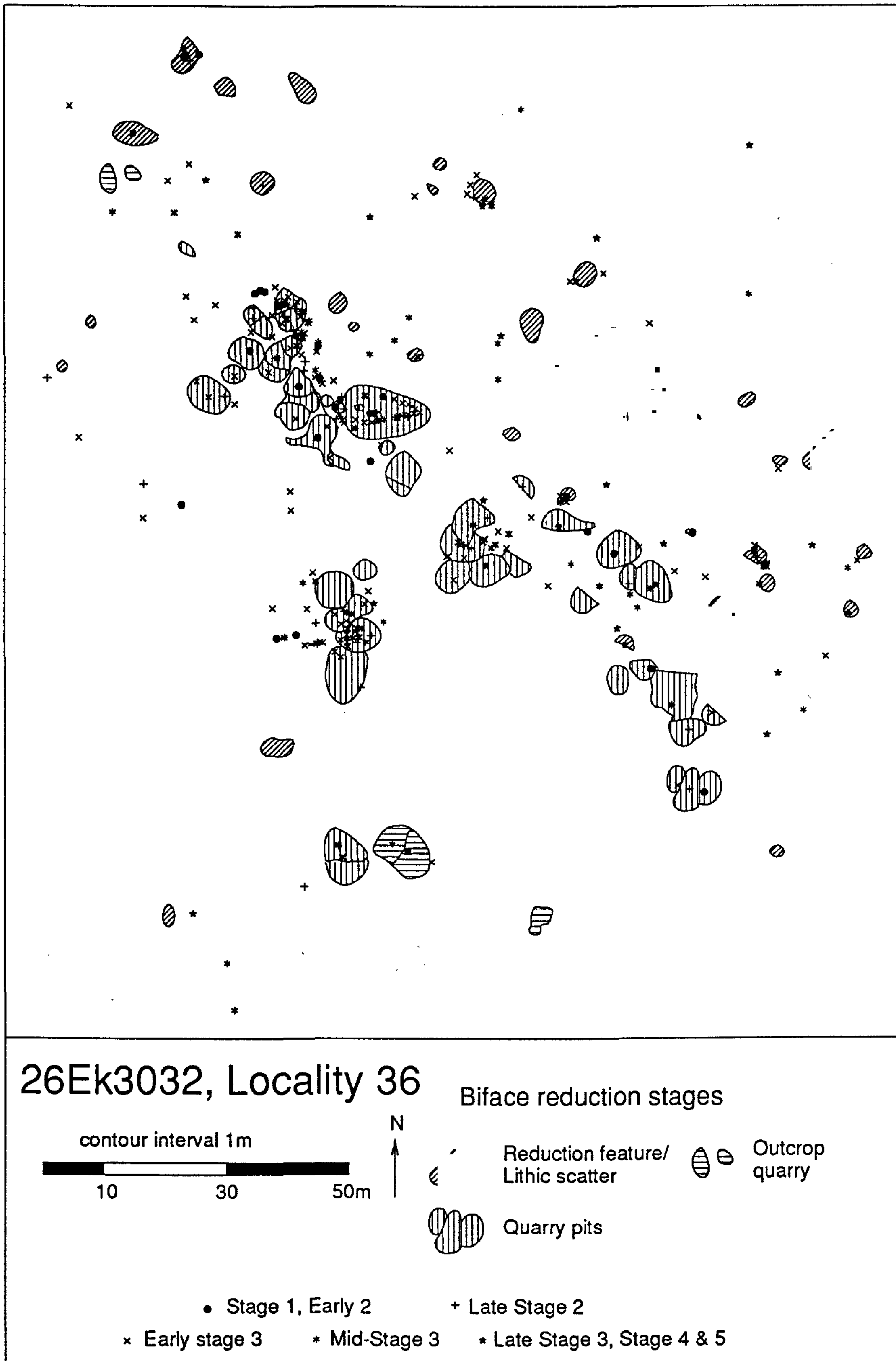


Figure 103. Distribution of bifaces by reduction stage.

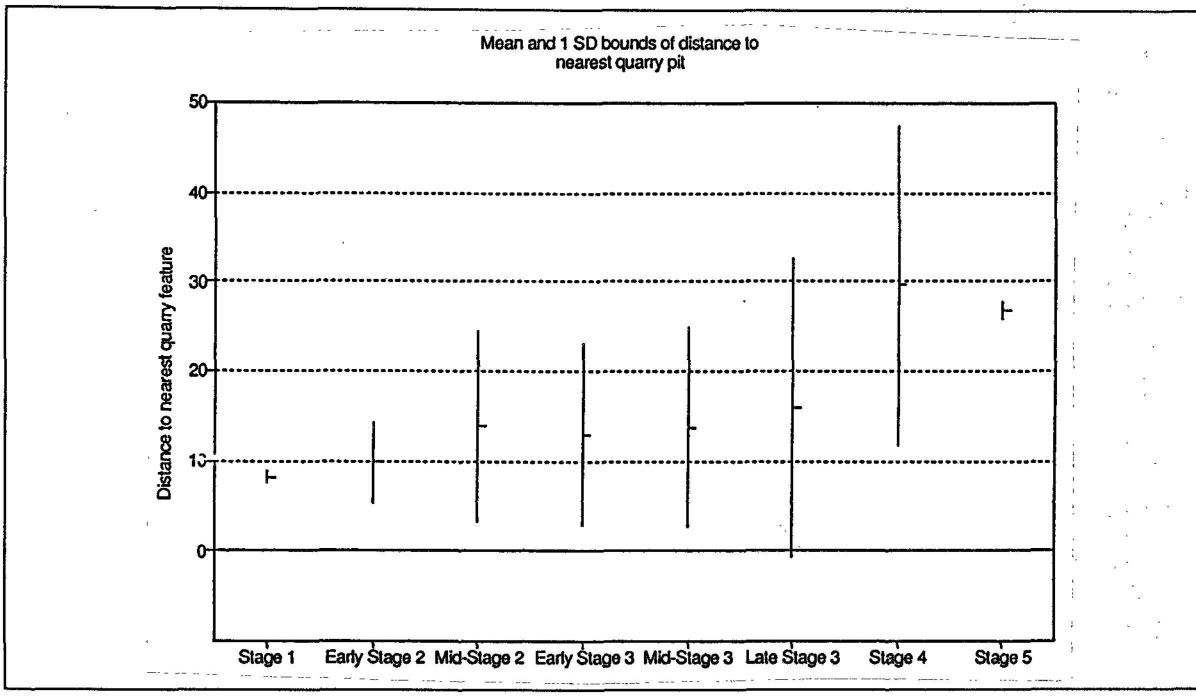


Figure 104. Mean and one standard deviation boundaries of distance from non-quarry pit bifaces to nearest quarry pit, by stage.

The 66 technologically analyzed samples were tallied using the techniques already described here and in Chapter 4 (Table 58). To compare the areas, we calculated the proportions of debitage samples within each area having a single characterization. Figure 106 compares these proportions. Area B and Area C are quite similar. Most samples from these areas have quarrying debris, mass reduction debris, and lower frequencies of blank preparation and early biface thinning. Late biface thinning is rare or absent. Area A differs from Areas B and C. Quarry debris is rare, and while mass reduction debitage is frequent as in Areas B and C, so are blank preparation and early biface thinning flakes. Area A, then, appears to have more biface production and less frequent quarry debris than the other quarry pit groups.

Table 58. Assemblage Summaries (frequencies) for Three Quarry Pit Complex Areas.

	QUARRY PIT COMPLEX		
Debitage	Area A	Area B	Area C
Q* or Q	5	11	19
q or none	25	1	5
M* or M	21	12	21
m or none	9	0	3
B* or B	23	6	14
b or none	7	6	10
E* or E	26	4	14
e or none	4	8	10
L* or L	0	0	1
l or none	30	12	23
BIFACES			
Early (Stage 1 to mid-2)	16	61	14
Late (mid-Stage 3 to 5)	22	16	30

Key:

Q = quarrying	Lower case: Trace Quantity
M = mass reduction	Upper case: Frequent
B = blank preparation	Upper case w/asterisk: Dominant
E = early biface thinning	
L = late biface thinning	

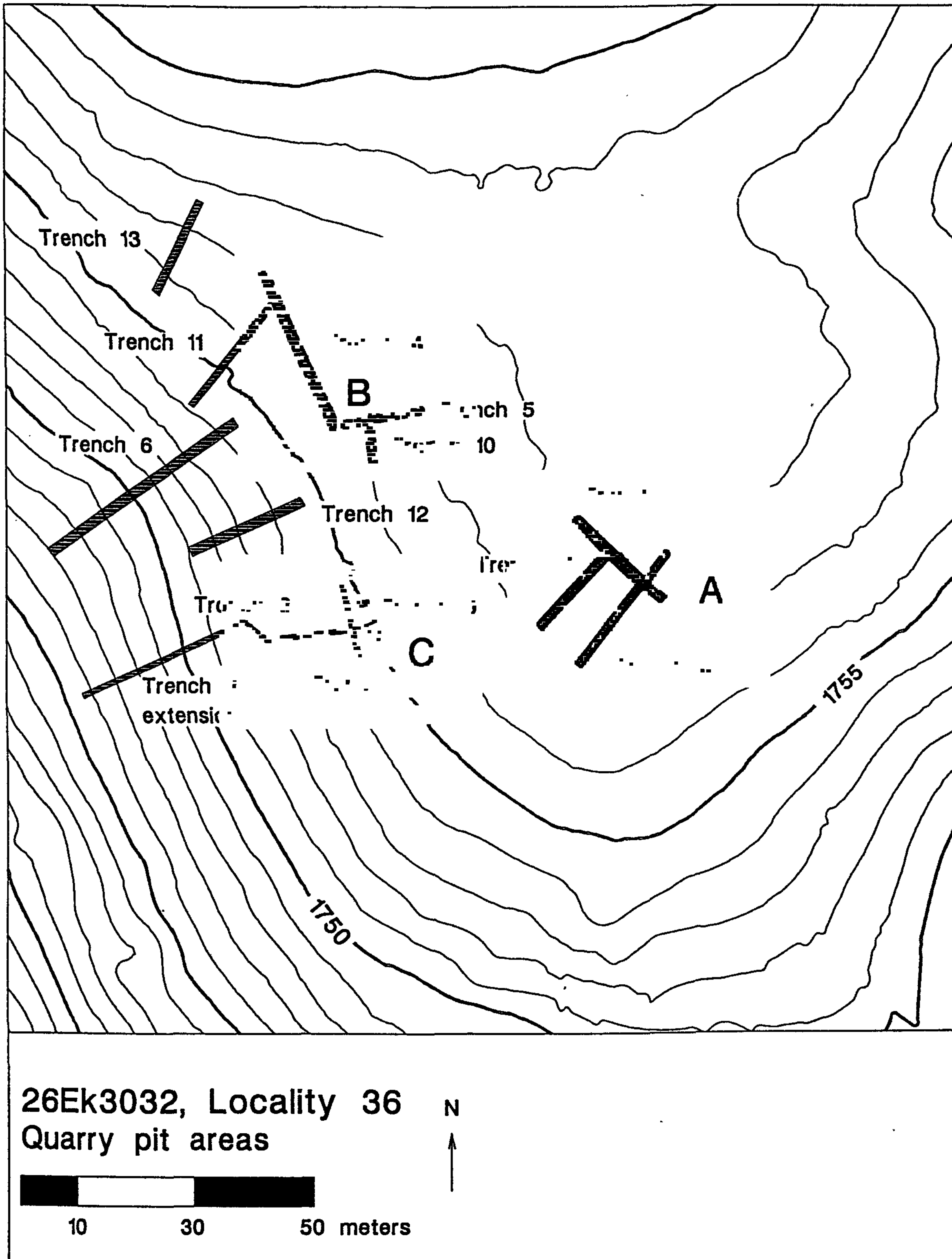


Figure 105. Quarry pit complex areas.

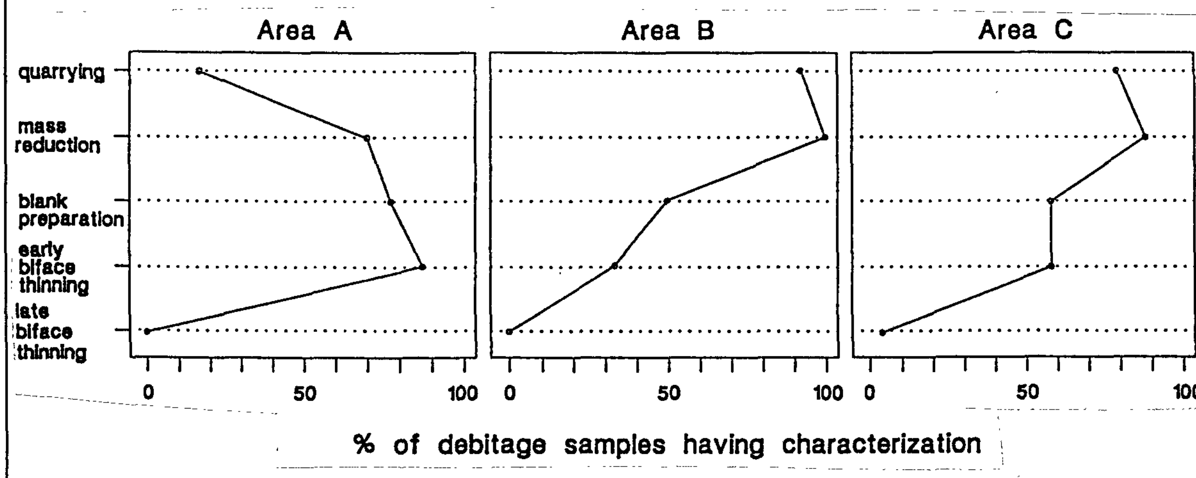


Figure 106. Dot plot of proportional frequency of individual technological characterizations of debitage samples, quarry pit Areas A, B, and C.

Another pattern emerges from examination of the reduction stages of bifaces recovered from each area. The bifaces from each subarea were grouped into early stage (Stage 1 to mid-Stage 2) and late stage (mid-Stage 3 to Stage 5) classes. They then were compared in a 2 by 3 cross-tabulation. The resulting chi-square value indicates that there is an association between early/late stage classes and quarry pit areas (Table 59). Adjusted standardized residuals (Table 59) indicate that in Areas A and C, late stage bifaces are more common than would be expected under a chi-square model of independence. In Area B, early stage bifaces are more common than expected.

Table 59. Contingency Table of Feature Context (Feature 102 vs. reduction features) by Early and Late Stage Biface Stage Frequency.

	FEATURE CONTEXT		
Biface Reduction Stage	Area A	Area B	Area C
Early (Stages 1 to mid-2)	16 (-2.16*)	61 (5.43*)	14 (-4.01*)
Late (mid-Stage 3 to 5)	22 (2.16*)	16 (-5.43*)	30 (4.01*)

chi-square = 30.37; df=2, $p>0.05$
(adjusted standardized residual, asterisk indicates $p<0.05$)

Hammerstone attributes (completeness, local vs. nonlocal material, frequency of basalt and quartzite hammerstones, and hammerstone weights) were tallied for each area. No differences in the attributes of the hammerstone assemblages were found among quarry pit areas.

Discussion

Distributional studies at Locality 36 show a variety of patterns; the purpose of this discussion is to consider how best to interpret them. Patterns appear at numerous levels in Locality 36, both within artifact classes and among them. Since spatial patterns are rarely direct testimony of individual activities in the past (Bartram, Kroll, and Bunn 1991; O'Connell, Hawkes, and Blurton-Jones 1991; Gregg, Kintigh, and Whallon 1991), attempting to see individual events in the Locality 36 patterns probably will be fruitless. A more productive approach to interpretation of spatial patterns is to consider how they suggest the overall organization of activities (Binford 1983).

How use of space was organized is an indirect indicator of the sorts of activities conducted within that space, since some activities require work space to be maintained whereas other activities do not (Binford 1983). Thus, the emphasis in the analyses above, and in the discussion following, is on how artifact and attribute distributions indicate spatial organization of work both at Locality 36, and perhaps more generally at all quarries.

Instead of reviewing each analytical result, this discussion attempts to synthesize all the results. It is intended to be integrative, drawing together the disparate patterns found above.

Quarry pit features, and the debris associated with them, dominate Locality 36 site space. Almost all distributions center on them, and there is a steady fall-off in the frequency of artifact classes with distance from them. Quarry pits are associated closely with exploitable opalite. Furthermore, once a quarry pit is initiated it becomes an access point for further quarrying—exploitation may expand out of a single pit, work an exposed face back and forth, or simply target adjacent areas because there is the likelihood of useful toolstone being found there too. The result of several thousand years of opalite extraction is that quarry features are embedded in debitage and opalite debris. Even when the topographic expression of pits and adits has been suppressed by erosion or burial, a distinctively large debris profile still characterizes bedrock extraction areas.

These characteristics of the Locality 36 extraction areas undoubtedly limited their utility for activities that require large areas of relatively clear space (e.g., domestic activities; cf. Binford 1978). From an organizational perspective—in terms of the limitations placed upon future actions in the same space—debris from quarrying restricted activities needing large areas of clear space (e.g., residential occupation). Quarrying debris would not have limited actions with less stringent space requirements, such as flintknapping which requires only a few square meters of workspace. If the activities performed in such spaces generate durable refuse, then they will yield strong spatial patterns that are detectable archaeologically.

Debris generated by repetitive actions may coalesce into accretional concentrations or "superfeatures." The debitage aprons at Locality 36 are probably a sort of "superfeature," composed of many discrete reduction feature/lithic scatters that overlap spatially. The debitage aprons are a mixture of debris generated by toolstone extraction and debitage created by toolstone processing. Debitage within the aprons can vary in size, perhaps due to the mode of extraction employed (e.g., around the outcrop opalite sources at Features 51 and 52), or due to the extent of overlap between different kinds of lithic reduction. As debitage analysis results have shown, however, these apron "superfeatures" differ in their technological genesis from reduction feature/lithic scatters and quarry pits, since they have more early reduction and extraction debris than the former, and more later reduction debris than the latter. As mentioned above, the ethnographic literature on quarrying suggests that bedrock (or other point-source) quarries should have associated satellite reduction areas (see also Elston and Dugas 1992). The debitage apron "superfeatures" probably are composed of many hundreds of such associated reduction areas.

Another sort of "superfeature" at Locality 36 is the quarry pit complex. Individual features can be distinguished on the surface of such complexes, but our investigations found quarry pits dug into the berms of older features. With enough quarrying activity in a small area, clusters of surface pits and a complex subsurface stratigraphy form, yielding quarry pit complex "superfeatures" that are accretional (although still distinctive) repetitions of the same type of feature.

Individual reduction feature/lithic scatters are at the other end of a scale of feature complexity from such "superfeatures." This feature type was recognized explicitly on the basis of discrete, definable, margins determined by a fall-off in debitage density. By definition, reduction feature/lithic scatters can occur only away from quarry pit complexes and debitage aprons. Two distance groups, relative to quarry features, were discerned in analysis. The nearer may be simply reduction feature/lithic scatters not yet agglutinated into debitage aprons, for they are only a few meters away from quarry pits. The near-quarry pit feature group is similar to ethnographically described satellite lithic reduction areas directly associated with toolstone sources. Reduction feature/lithic scatters farther from quarry pits, such as those on the central ridgetop at Locality 36, may indicate a very different spatial organization. They have a high incidence of biface reduction, generally cover more area than features in the group nearer to quarry pits, and may be associated with buried hearths suggesting that they are fairly young (perhaps ca. 500 years or less in age).

Features reflect how space use was organized within Locality 36, but not what actions occurred in specific places or kinds of places. The distribution of debitage characterizations, stone tools, and stone tool attributes informs on this topic. Since the focus of almost all known prehistoric activities at Locality 36 was biface production, the following description integrates major spatial patterns into a thumbnail sketch of the spatial organization of toolstone extraction and stone tool production.

The extraction of toolstone involved a significant investment of labor (cf. Chapter 9, Chapter 12). Extraction efforts were restricted to areas where opalite could be exposed easily, i.e., the western slope of the central ridge. Extraction debris was widespread, scattering out from quarry pits and becoming part of the debitage aprons around them. It cannot be ascertained just how widely tuff, useless hunks of opalite, dirt, and other detritus from quarrying were spread from any given pit: churning, reworking, and engulfment in the debitage and debris carpets make this impossible.

Tools used in opalite extraction consisted of both local and nonlocal hammerstones. Opalite hammerstones appear to have been used in expedient fashion. Perhaps because they were less durable, or simply easier to obtain, they frequently were discarded unbroken within quarry pits. Although hammerstones of nonlocal material also were used in quarrying, they were discarded in quarry pits less often, and they commonly are found, broken, in reduction features.

Following extraction of toolstone pieces, initial core reduction occurred in four settings: in the quarry feature itself (or perhaps in a nearby inactive quarry pit); in the debitage apron where core reduction debitage forms part of the apron matrix; in reduction feature/lithic scatters; and in non-feature settings, where it never occurs in sufficient density to form a reduction feature/lithic scatter on its own. Core reduction is the most spatially extensive of all lithic reduction activities, suggesting that it was least organized or had the fewest concomitant space requirements.

Blank preparation and early biface thinning debitage commonly occurred in three settings: in quarry pits (again, whether pits were actively quarried at the time cannot be determined); within the debitage apron or in the "near" group of reduction feature/lithic scatters, i.e., quite near quarry pits; and in the "far" group of reduction feature/lithic scatters. Blank preparation and early biface thinning was the predominant lithic reduction activity in more distant reduction feature/lithic scatters. With only one exception, blank preparation flakes and early biface thinning flakes in the other two settings are simply two ingredients in a heterogeneous mix of debris and debitage. The sole exception is Feature 102, the oldest quarry pit known. Although not statistically significant when the *incidence* of early biface thinning is compared to that of other settings, the *frequency* of early biface flakes appears to be much greater than that of any other quarry pit deposit or even of the debitage apron. On the basis of debitage alone, it seems that prehistoric knappers were relatively indifferent as to where they produced early stage bifaces. Biface reduction flakes were not produced, however, in the same roving fashion as mass reduction flakes, since in all contrasts they are associated inversely with the non-feature setting.

Late biface thinning is associated with only two settings at Locality 36. Late biface thinning flakes and late stage bifaces were found in reduction feature/lithic scatters and in the non-feature area. Late biface thinning occasionally was undertaken at Locality 36, but both the debitage assemblage (cf. Chapter 4) and the biface assemblage (cf. Chapter 5) show that it was far less common than was early biface thinning.

The biface assemblage demonstrates a pattern of associations with feature contexts different from that of debitage. Overall, bifaces were discarded most often in quarry pits, but biface reduction stage (and attributes related to stage) have clear spatial patterns. Early stage bifaces were discarded most often within quarry pit contexts, were not heat-treated, and were complete, having been made on block blanks. Late stage bifaces were more common in reduction feature/lithic scatters where they were heat-treated significantly more often, were broken, and were produced from flake blanks. The latest stage bifaces were found in the non-feature area. Feature 102 has a biface assemblage more similar to that from reduction feature/lithic scatters than to that from quarry pits.

Presuming that bifaces were discarded in the contexts where they broke or otherwise were found unsuitable, a scenario of biface production as a whole can be sketched, incorporating both debitage and biface distribution studies. The reader should bear in mind that debitage suggests where reduction occurred, and the biface assemblage suggests where reduction failed. Initial blank preparation and early biface thinning occurred in contexts which we recognize as archaeological features. It was most often unsuccessful within quarry pits, either due to the block blanks on which the bifaces were produced or because the bifaces discarded there constitute the unsuccessful portion (i.e., the block blank bifaces that were successful were reduced beyond the point of recognition). When bifaces or biface blanks (often flake blanks) were removed from the quarry pit and quarry apron area to more distant parts of the site (more than about 20m from quarry pits) they were reduced further and heat-treated. Late stage biface production (Stage 4 and Stage 5) is rare at Locality 36, but when it did occur it almost always was removed from quarry pit areas.

Feature 102 is an interesting exception to much of the foregoing scenario, which raises the issue of change through time in how space was used at Locality 36. The distribution of swirled opalite from Feature 102 suggests that its use was often, but not invariably, during the "active" life of the feature. During its period of use, Feature 102 seems to have been a combination of quarry pit *and* reduction feature, as if the two contexts were not separate at all. If one hypothesizes that as quarry use becomes more intense the need to separate activities becomes greater, then perhaps Feature 102 attests to an early small-scale (but large-effort) use of Locality 36.

Change through time is suggested in the comparison of the three superfeature quarry complexes. Area A, youngest of the three, is therefore latest in reduction stages present, both in debitage incidence and bifaces. Area C, the oldest, also has a late biface assemblage (even when Feature 102 is removed from comparison), but has early debitage. Area B, intermediate in age, has both early debitage and early stage bifaces associated with it. These differences suggest change in the organization of where bifaces were produced. For example, during the period in which Area B was used, perhaps most later biface production occurred away from quarry pits, in spatially separate contexts now forming part of the debitage apron. In Area C, the coincidence of early biface thinning debitage and late bifaces could indicate that biface thinning occurred away from the quarry pit itself, but close enough that failed bifaces found their way back into the quarry features. Lastly, the entire production of bifaces may have occurred in a restricted spatial area in Area A.

The latest use of Locality 36, associated with Area A, is also likely to have been when discrete reduction features were established on the ridgetop. This suggests that biface reduction required the space around the quarry pits in Area A *and* sometimes additional work spaces (which we see as reduction feature/lithic scatters).

Distributional studies at Locality 36 have revealed much of the structure of biface production as well as use of the place. The gross patterns of debitage frequency probably are "signatures" of almost any quarry locality (although this remains unproven). Bedrock toolstone extraction creates a unique spatial signature of large debris from spatially extensive actions. Large debris also can occur away from extraction locales, if blocks are carried away from the pits for processing. Elsewhere, we have argued that such effort is rarely worthwhile energetically (Elston and Dugas 1992), even over distances of 100m or less. As expected, there is no evidence of large block transport farther than 10 to 20 meters from the Locality 36 quarry pits. In the main, areas removed from quarry pits should be dominated by small debris from activities less messy than toolstone extraction. Tool production is certainly one expected activity of this sort, as are routine domestic chores. Ample evidence of tool production away from quarry pits was found at Locality 36. No unequivocal evidence of domestic activity was found.

Chapter 11

THE ARCHAEOLOGY OF LOCALITY 221

Kristopher R. Carambelas, Kathryn Ataman, Eric E. Ingbar, and Dave N. Schmitt

Locality 221 lies at 5655 feet (1724 m) amsl and occupies the northern slope of a low, southeast-trending finger ridge emanating from Lower Red Hill in the southernmost portion of 26Ek3032 (Figure 107). The locality is a small (ca. 20 m diameter), isolated, light density opalite scatter associated with low opalite bedrock exposures (Figure 108). Toolstone scattered across it is a distinctive, high quality, off-white opalite with occasional swirls of red and pink, probably derived from bedrock deposits within the locality with the same distinctive coloring; on-site exposures, however, lack clear evidence of toolstone removal.

Data recovery at Locality 221 offered an opportunity to address several regional research issues (Intermountain Research 1988a) pertaining to the strategies and economics of toolstone procurement and reduction. The locality represents the southernmost exposure of toolstone within 26Ek3032, perhaps one of the first toolstone sources encountered by people accessing the quarries from the Humboldt River vicinity and other points south. It was suggested that, by virtue of its low intensity use and its peripheral location, quantitative and qualitative data might offer an opportunity to examine exploitation of a poorly represented source type (Intermountain Research 1990b:9). The present chapter suggests that the locality functioned as a biface reduction locus, and that toolstone probably was extracted from bedrock exposures or secondary cobbles within it.

Data Recovery Procedures

Field procedures reflected those employed at Locality 36 (cf. Chapter 3). Data recovery was intended to characterize the contents and spatial structure of the locality and define the assemblage composition and subsurface extent of buried cultural deposits. Field work commenced with an intensive surface reconnaissance for features and formed artifacts. No features were discovered, but all formed artifacts were collected and their locations flagged for instrument mapping.

A representative sample of surface artifacts was obtained by randomly placing 10 50 cm x 50 cm surface scrape collection units across the locality (Figure 109). One 1 m x 1 m unit was excavated adjacent a bedrock exposure in the center of the site to explore subsurface deposits and examine the outcrop for evidence of on-site quarrying (i.e., pits or adits); two 1 m x 1 m units were excavated north and south of the exposure to determine whether subsurface cultural deposits existed away from possible quarry features. Two units contained 50 cm by 50 cm control quadrants, material from which was screened through 1/8 in. mesh; the remaining material was sifted through 1/4 in. mesh. All three units were excavated to 20 cm below surface, the level at which clays and weathered tuff bedrock were encountered and artifact frequencies decreased.

Contours, units, and the locations of formed artifacts and outcrop exposures were mapped (cf. Figure 109). Table 60 details the work.

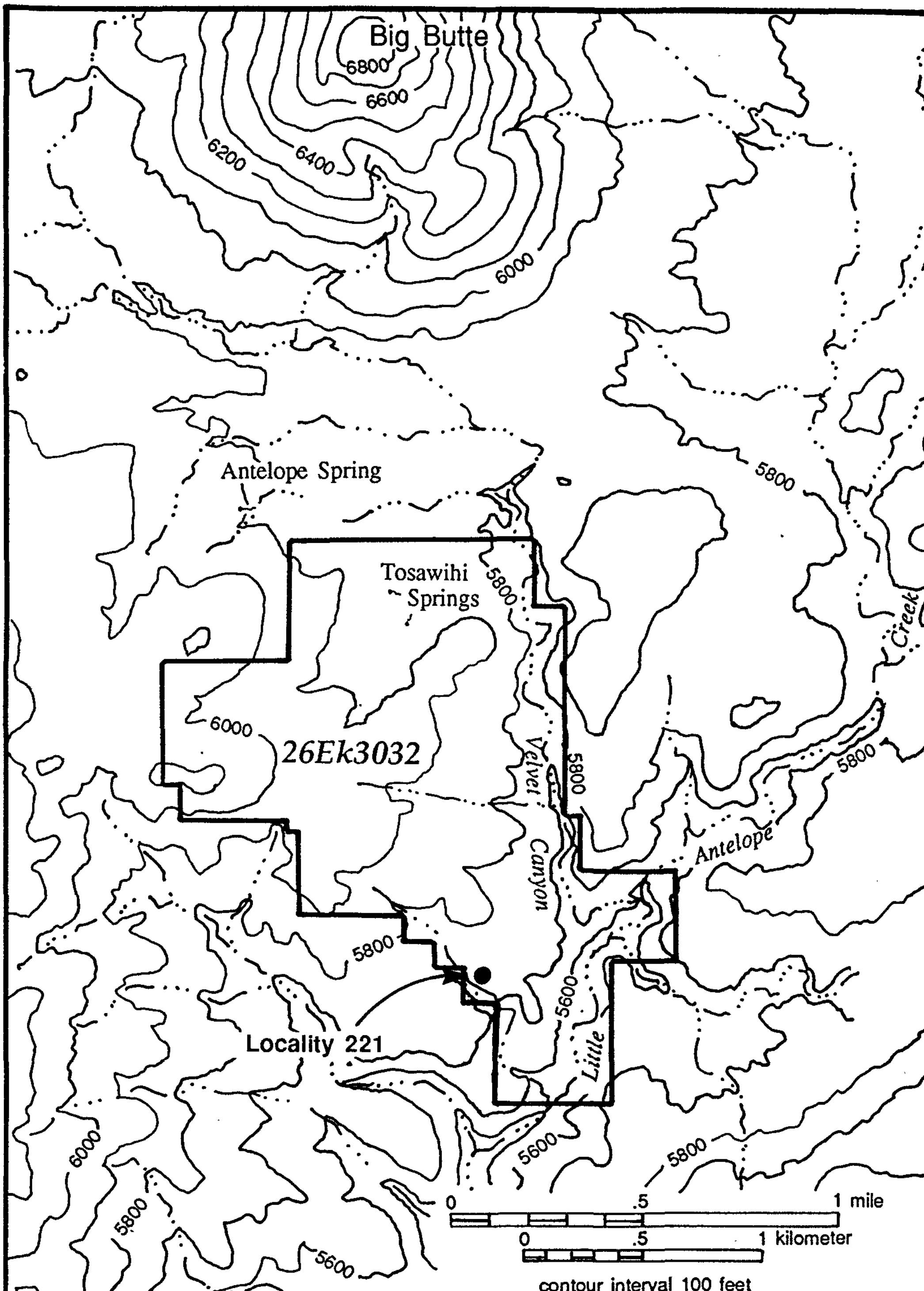


Figure 107. Location of Locality 221 relative to 26Ek3032 boundaries.

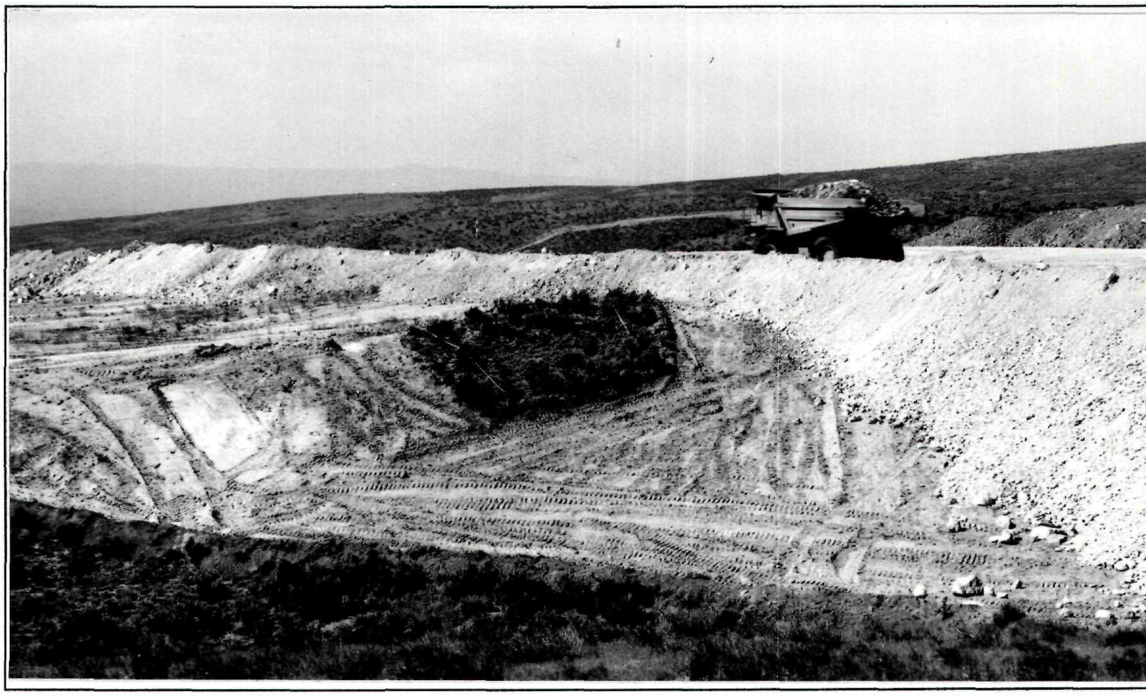


Figure 108. Overview of Locality 221.

Table 60. Concordance of Unit Type, Number, Reference, and Level of Excavation.

Unit Type and Number	Level	Unit Type and Number	Level
DSC 1	Surface	EU 11*	2-10 cm
DSC 2	Surface	EU 11	10-20 cm
DSC 3	Surface	EU 11*	10-20 cm
DSC 4	Surface	EU 12	Surface
DSC 5	Surface	EU 12*	Surface
DSC 6	Surface	EU 12	2-10 cm
DSC 7	Surface	EU 12*	2-10 cm
DSC 8	Surface	EU 12	10-20 cm
DSC 9	Surface	EU 12*	10-20 cm
DSC 10	Surface	EU 13	Surface
EU 11	Surface	EU 13	2-10 cm
EU 11	Surface*	EU 13	10-20 cm
EU 11	2-10 cm		

* Control unit; material screened through 1/8 in wire mesh.
DSC: Surface Collection Unit
EU: Excavation Unit

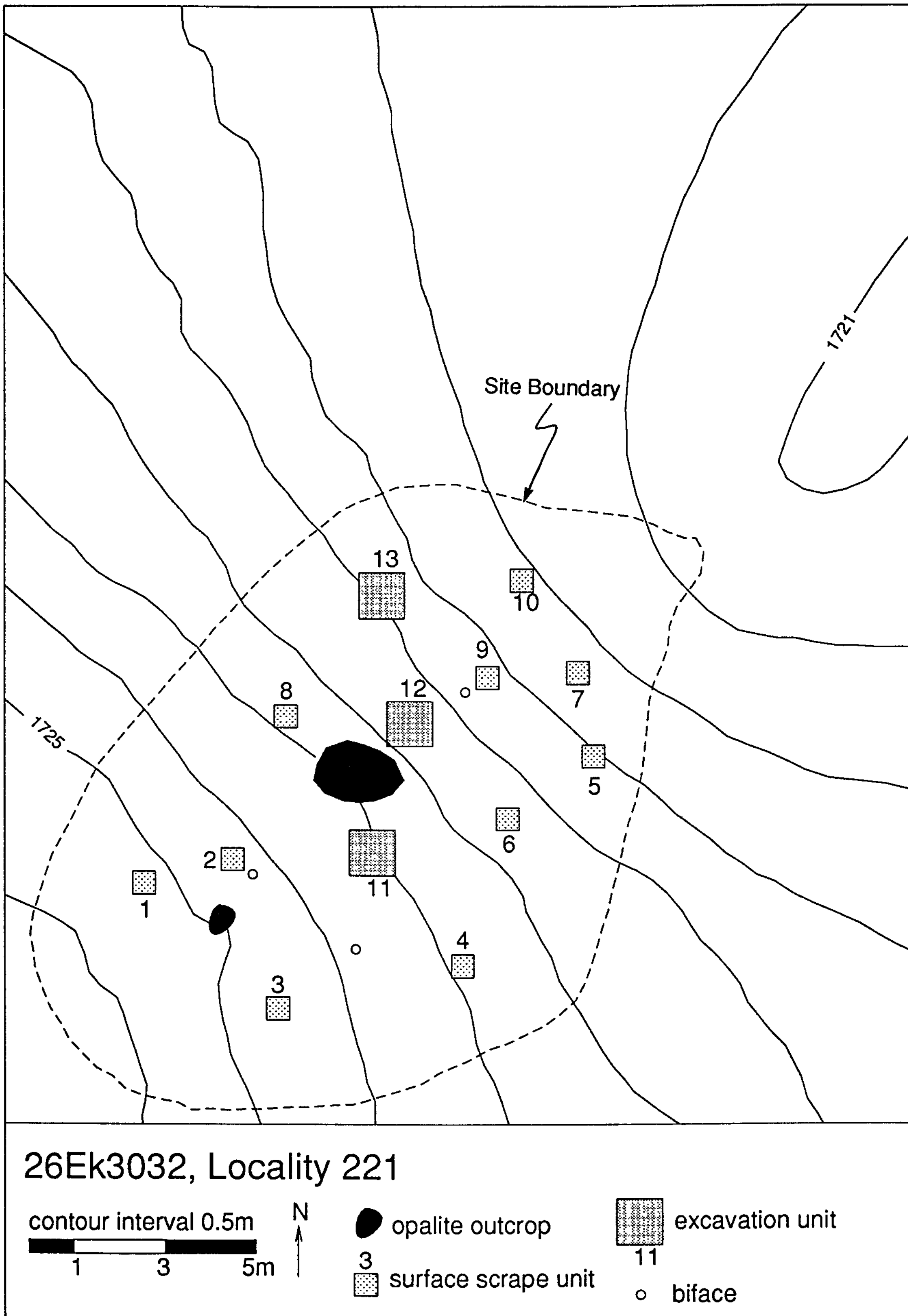


Figure 109. Topographic and unit location map of Locality 221.

Results

Subsurface cultural materials occur across the site. However, no features related to quarrying or evidence of toolstone removal from parent material were observed adjacent the bedrock outcrop. Recovered artifacts were limited to three non-diagnostic tools and a host of lithic debitage; analyses are presented below. Chapter 12 incorporates these results in a more general discussion of strategies of toolstone extraction and processing.

Biface and Debitage Analysis

The goals of analyses were to identify the types of reduction activities that created archaeological deposits at Locality 221 and to interpret the observed spatial patterning of the resulting debris. Specifically, we were concerned with the origin of the raw material, the nature of reduction technology, the extent to which raw materials were reduced, and the degree to which they were heat-treated.

The small size of debitage samples recovered precluded use of rigorous quantitative analytical methods, so debitage from each unit was analyzed by the qualitative typological technique outlined in Chapter 3. Additional data collected during analysis included the counts and weights of whole flakes and the weights of angular debris (Table 61). Results of the analysis are presented in Table 62.

Table 61. Counts and Weights of Debitage.

Unit Number	Level	Flake Count	Flake Weight (gm)	Angular Debris Weight (gm)	Unit Number	Level	Flake Count	Flake Weight (gm)	Angular Debris Weight (gm)
1	Surface	0	0.0	0.0	11	2-10 cm	8	372.6	2303.3
2	Surface	1	0.2	21.3	11*	2-10 cm	110	105	562.9
3	Surface	2	0.8	0.4	11	10-20 cm	30	85.2	136.2
4	Surface	27	79.3	27.5	11*	10-20 cm	23	209.6	2.5
5	Surface	31	149.7	3.8	12	Surface	103	159.3	137.3
6	Surface	4	3.8	10	12*	Surface	49	118.7	8
7	Surface	6	4.5	2.1	12	2-10 cm	77	230.1	468.5
8	Surface	20	68	55.3	12*	2-10 cm	48	59.8	6.6
9	Surface	20	36.9	68.9	12	10-20 cm	15	40.2	48.8
10	Surface	5	3.3	12.4	12*	10-20 cm	36	37.9	0.2
11	Surface	24	218	145.4	13	Surface	7	9.3	1.9
11*	Surface	0	0.0	0.0	13	2-10 cm	10	196.5	10
					13	10-20 cm	11	20.1	91.5
Totals							667	220.8	4124.8

Of the 25 debitage samples analyzed, 14 (56%) contain evidence of blank production and 11 (44%) contain evidence of Stage 2 edge preparation. Blank preparation (the removal of major irregularities from a flake blank; cf. Bloomer and Ingbar 1992), is apparent in only 6 (24%)

samples. This suggests that flank blanks produced at Locality 221 needed little modification prior to Stage 2 reduction because they already were fairly thin and regular. Evidence for primary biface thinning (Stage 3; cf. Callahan 1979:90-115) is present in 22 (88%) of the samples: 9 (36%) contain flakes produced in the course of early Stage 3 thinning; 6 (24%) contain flakes produced during late Stage 3 thinning; 7 (28%) have Stage 3 flakes that could not be classified. These data suggest that Stage 3 thinning occurred across most the site. No evidence of later stage thinning was evident.

Table 62. Results of Qualitative Typological Analysis.

Unit Number	Level	ND	BPRD	BPRP	EPRP	S3E	S3L	S3I	XL	HT
1	Surface									
2	Surface	X								
3	Surface	X								
4	Surface			X		X				
5	Surface		X			X				
6	Surface							X		
7	Surface		X					X		
8	Surface		X	X	X	X				
9	Surface		X		X	X				
10	Surface		X			X				
11	Surface		X		X			X		
11*	Surface									
11	2-10 cm		X	X	X			X		
11*	2-10 cm		X		X		X			
11	10-20 cm		X				X			
11*	10-20 cm		X	X						
12	Surface				X	X	X			
12*	Surface		X		X			X	X	
12	2-10 cm			X	X	X		X		
12*	2-10 cm			X		X	X		X	X
12	10-20 cm		X			X				
12*	10-20 cm				X		X			
13	Surface				X				X	X
13	2-10 cm		X					X	X	
13	10-20 cm	X	X		X		X			
Totals		3	14	6	11	9	6	7	4	2

* Control unit; material screened through 1/8 in. wire mesh
ND=Non-Diagnostic EPRP=Edge Preparation S3I=Indeterminate Stage 3 Biface
BPRD=Blank Production S3E=Early Stage 3 Biface XL=Extra-Locale Material
BPRP=Blank Preparation S3L=Late Stage 3 Biface HT=Heat-Treatment

The debitage assemblage is composed almost entirely of non-heat-treated material almost certainly deriving from outcrops within the locality. Extra-local lithic material, observed in only four (16%) samples, includes one quartzite hammerstone spall and three chalcedony flakes. Each chalcedony flake reflects Stage 3 reduction and exhibits differential luster, a characteristic of debitage removed from heat-treated bifaces. As at other Tosawihi sites, (cf. Bloomer, Ataman, and Ingbar 1992), bifaces often were heat-treated *during* Stage 3 reduction.

Only three bifaces (two complete and one fragmentary) were recovered from Locality 221. Each appears to have been manufactured from on-site material, and none is heat-treated. One complete biface was initiated on a flake blank and reduced to Stage 2 prior to discard; relatively small width/thickness ratio (1.71) may account for its abandonment. Amick (1985:144) has noted that the presence of bifaces 'without failures' early in the reduction trajectory probably reflects inability to thin the artifact, which was abandoned due to decreasing margin width. The other complete biface was produced from a block blank and reduced to early Stage 3 prior to its abandonment. The incomplete specimen consists of an end fragment produced by edge collapse during longitudinal thinning; it appears to have been reduced to Stage 3 prior to failure.

Spatial Patterning

Figure 110 plots the distribution of reduction stages (as indicated by debitage) across the locality. Tools and the location of heat-treated chalcedony are plotted as well. Blank production through late Stage 3 thinning occurs across most of the site, but the number of reduction stages increases near the largest bedrock outcrop. Flake counts and weights and the weight of angular debris (cf. Table 61) also increase near the outcrop. Two pieces of heat-treated chalcedony and a quartzite hammerstone spall were recovered from this area. Elsewhere, chalcedony occurs only at the northern end of the site. From these data, it appears that the reduction of local and extra-local materials was conducted primarily near the largest bedrock outcrop in the center of the locality.

Discussion

Goals of the present analysis include determining the geological origins of the lithic assemblage at Locality 221, the reduction techniques that created the artifacts, and the degree to which artifacts were heat-treated. Most artifacts exhibit the same texture and color as the stone outcrops; exceptions include one quartzite and three chalcedony flakes, comprising less than one percent of the total flake assemblage (n=667). However, evidence for toolstone extraction is absent. It is likely that prehistoric quarry features have been obscured by erosion on the steep slope (~10°) of the site, or that they now are covered by colluvium (cf. Chapter 8). We strongly suspect that the artifacts were derived from parent material at the locality.

Given the results of artifact analysis, it seems reasonable to suggest that biface production was the primary activity carried out at Locality 221. Biface production was initiated on large flake blanks (rather than on core blanks) that needed little modification prior to Stage 2 reduction, and it continued through Stage 3 (cf. Callahan 1979:33-35). Completed bifaces then were transported elsewhere for use or further reduction. Local materials were not heat-treated at the locality, but at least one Stage 3 biface manufactured from an extra-local, heat-treated chalcedony was brought there and subsequently flaked.

It is difficult to assess the spatial organization of biface production at Locality 221 because reduction activities are not strongly patterned. More artifacts were recovered from units central to the site; however, evidence for blank production through Stage 3 thinning occurs in most samples. Patterns that once existed may have been obscured by the movement of artifacts and sediments down the steep slope.

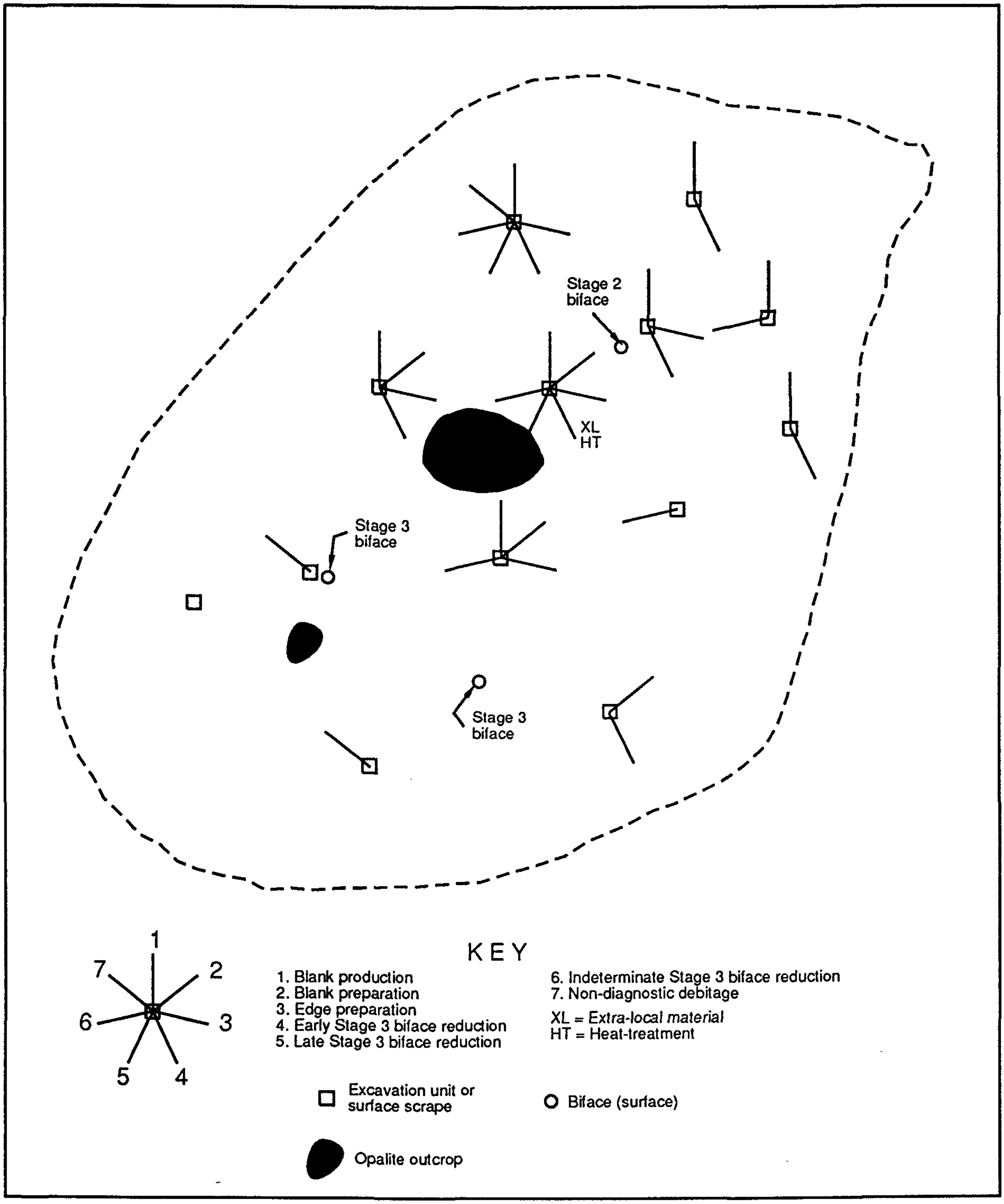


Figure 110. Star plot of reduction stages and extra-local material at Locality 221.

Conclusions

Both the artifact assemblage and geographic location of Locality 221 suggest that it was used for toolstone extraction and biface production. The site is located on a steep slope, and has no other associated resources. Except for a few pieces of extra-local material—one probably derived from a hammerstone—procurement and production activities focused exclusively on opalite. The lack of quarry features suggests that toolstone was procured from bedrock outcrops that are no longer visible or from secondary cobbles or boulders. It appears that Locality 221 offered a limited amount of quality toolstone for a small investment of time and effort. Based on its position relative to the southernmost limits of toolstone outcrops at the Tosawihi Quarries, as well as the minimal investments of time and energy needed to extract toolstone packages from it, we suspect that the locality was perhaps one the first places exploited by groups entering the quarries from the south. Unfortunately, the absence of time diagnostic artifacts and organic material for radiocarbon dating make this hypothesis untestable.

Chapter 12

THE ECONOMICS OF TOOLSTONE EXTRACTION AND PROCESSING

Kathryn Ataman, Kristopher R. Carambelas, and Robert G. Elston

This chapter examines the ways in which Tosawihi quarriers manipulated benefits and costs of quarrying at Locality 36. We look first at technological organization, then at strategies of extraction and processing.

Recall that one assumption of our economic model (cf. Chapter 1; Elston 1992c) is that foragers seek to maximize the benefit/cost ratio of toolstone procurement, thus achieving the greatest *efficiency* (Christenson 1980; Torrence 1986, 1989). We argued that toolstone confers no direct benefits, and that its utility is realized only by its ability to increase the return of other resources. However, since toolstone utility must be amortised over some interval subsequent to its procurement, one might never obtain utility equal to or greater than the time and energy invested in toolstone acquisition. The probability of such loss is *venture risk* (Elston 1992c). Thus, we reasoned, prudent foragers should seek to minimize venture risk by increasing the benefit/cost ratio of toolstone procurement.

This formulation, however, is a bit too simplistic because, while foragers can employ strategies that lower the time and energy invested in toolstone procurement, they also can invest more in order to increase the net rate of return, or *profitability*. As we shall see, changing the return rate may either increase or decrease efficiency (raising or lowering the benefit/cost ratio) and still minimize venture risk.

We suggest in Chapter 1 that cost minimization strategies are applied best to the indirect costs of toolstone procurement, such as lost opportunity and local subsistence, through manipulation of scheduling, labor organization, positioning, and activity segmentation. These strategies are manifest in the archaeological record as variability in site location, activity segmentation, and assemblage content, all of which have been investigated intensively by previous work at Tosawihi (Elston and Raven 1992; Leach and Botkin 1992). One reason to avoid giving a lot of weight to cost minimization or efficiency strategies is that constraints commonly decrease choices available for that option, particularly among the direct costs of toolstone procurement (e.g., time and energy for search, extraction, and processing).

For example, the kinds of toolstone and procurement opportunities available to hunter-gatherers are given by the lithic terrane in which they operate, while existing technology and physiological limits restrict possible techniques and strategies for lithic extraction, processing, and transport. Let us imagine that there are only three basic procurement strategies, listed in order of increasing cost as calculated for the duration of the foray: encounter procurement (glimpse and grab an isolated piece), intensive surface collection (spending time in a surface patch of toolstone), and quarrying (excavation for toolstone; cf. Elston 1992c). Theoretically, a forager can vary the benefit/cost ratio of toolstone procurement by choosing among the three strategies, but *only* if the lithic terrane is such that all three are possible. Otherwise, fewer potential opportunities for cost minimization will be available through strategic choice.

Strategies that emphasize efficiency (cost minimization) are likely to do so at the expense of intake. Consider that, while it is possible to reduce time and energy invested in toolstone procurement by relying only on encounter (the cheapest strategy over the short run), little toolstone is likely to be produced except in the richest lithic terranes where encounter rates are extremely high; in short, nothing ventured, nothing gained. Yet, such a cost-minimizing strategy may not be viable if task demands, or overall fitness, depend on acquisition of some minimum toolstone utility per unit time.

In modeling benefit/cost models of lithic procurement, the interval over which cost should be averaged is relevant to choice of procurement strategy when several are possible. If the benefit of toolstone procurement is grams of material and if the cost is time, one can calculate costs over a continuum ranging from the duration of a particular procurement episode, to a season of procurement, a year, or a lifetime. Hypothetical net returns for different strategies are graphed in Figure 111 and modeled in Table 63. In the first 10 minutes (interval A), encounter procurement produces a return of 10 grams for a benefit/cost ratio of 1.0, while intensive surface collection and quarrying entail non-productive activities such as prospecting and testing. In 100 minutes (interval B), encounter procurement, limited by the toolstone encounter rate of this particular patch, has produced no additional material, and its benefit/cost ratio, based on the initial 10 grams, falls to 0.1; quarrying, now involving overburden removal, has continued to produce nothing. In the meantime, however, surface collection yields 100 grams for a benefit/cost ratio of 1.0. At 500 minutes, quarrying has produced 1000 grams of toolstone for a benefit/cost ratio of 2.0, but at previous encounter rates, neither encounter procurement nor surface collection has produced additional material, and their benefit/cost ratios are orders of magnitude lower.

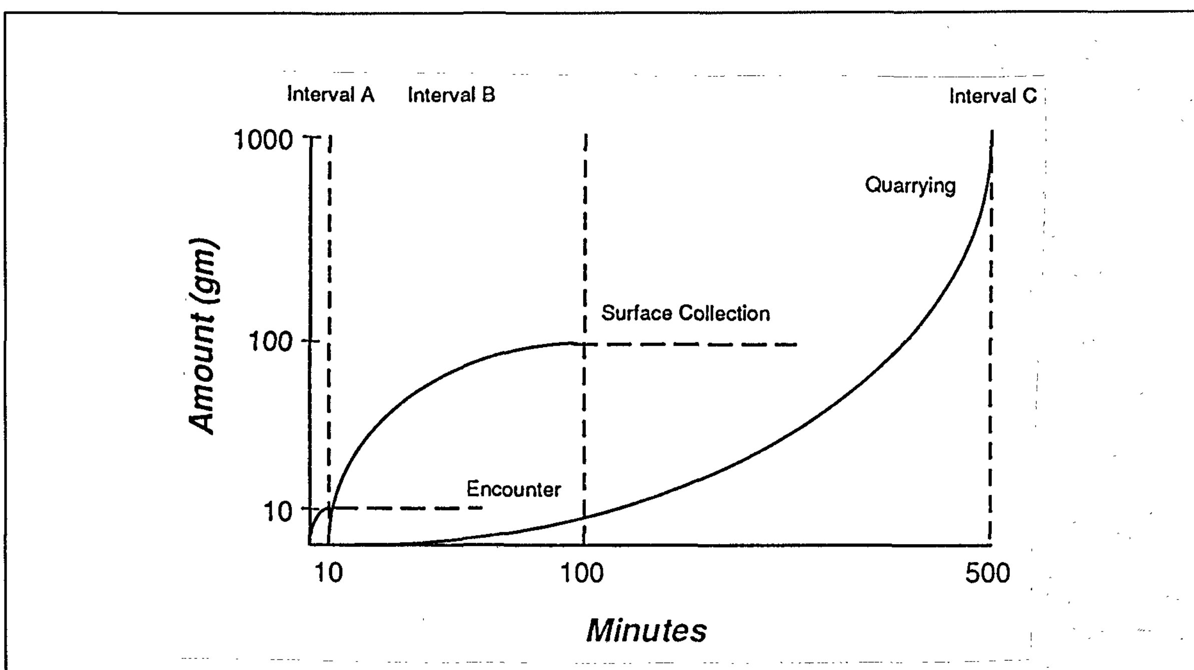


Figure 111. Hypothetical net return rates for encounter procurement, surface collection and quarrying.

Table 63. Hypothetical Benefit/Cost (B/C) Ratios for Three Lithic Procurement Strategies.

	Maximum gm per Episode	B C @ Interval A 10 min.	B C @ Interval B 100 min.	B C @ Interval C 500 min.
Encounter	10	1.0	0.1	0.02
Surface Collection	100	0.0	1.0	0.2
Quarrying	1,000	0.0	0.0	2.0

This exercise suggests that if foragers base strategic lithic procurement decisions on short-term efficiency (highest benefit/cost ratio), they always should choose encounter procurement or surface collection over quarrying, even when encounter rates are relatively low. Since, however, we cannot deny the existence of Tosawihi Quarries, we must assume that prehistoric foragers frequently took a longer view. Indeed, over the interval of a day (ca. 500 minutes), or longer, quarrying clearly is the better choice. If some minimum amount of toolstone is required, averaging cost over even longer periods is necessary to make the right decision. For example, if encounter rate limits the yield of encounter procurement to 10 grams per 500 minutes of search and processing time, it would take 50,000 minutes (nearly .10 person year) to obtain the 1000 grams of toolstone procured in 500 minutes of quarrying in our model.

Our modeling exercise also illustrates the difference between the goal of efficiency and that of achieving the greatest profit (Stephens and Krebs 1986:9). In the example above, the *efficiency* (benefit/cost ratio) of 10 minutes of encounter procurement and 100 minutes of surface collection is the same (1.0), but the *profit* (net return) of surface collection is 10 times greater. Of all techniques for toolstone procurement, quarrying bedrock is the most labor intensive, but has the greatest potential for return. In our model, the cost of quarrying is 50 times that of encounter procurement, but the net return is 100 times greater. Although rate maximization *may* result in increased efficiency (as in our example), this is not necessarily true in every case. If we decrease the yield of quarrying in our model to 450 grams in 500 minutes, efficiency falls to 0.9, but net return (profit) still is 4.5 times that of surface collection over the same interval.

At first glance, a rate maximizing strategy seems to increase venture risk, simply because short term labor investment is so much higher. This is true to the degree that return cannot be predicted, but, as we have suggested previously, one of the great advantages of quarrying over other forms of procurement is the increased predictability of return. Thus, we argue, people establish quarries in order to increase *profitability* without increasing venture risk.

Indeed, bedrock quarries such as Tosawihi are *prima facie* evidence that foragers preferred rate maximizing over cost minimizing strategies of toolstone procurement in some contexts. Once quarriers have decided to extract toolstone from a particular source, although constrained technologically, variability in the toolstone gives them some latitude for choice in whether to go for lower cost or better return rates. However, the archaeological record frequently does not allow the two to be distinguished. Foragers seem likely to emphasize return rates when a minimum amount of toolstone must be procured over a particular interval. The intensification of quarrying at Tosawihi and the tendency to pursue ever more costly material through time suggests that maximizing goals became increasingly important there, particularly through the Late Prehistoric.

We devote considerable discussion in this chapter to the following question: Given the decision to quarry opalite at Locality 36, what was the relationship of efficiency to rate maximization in toolstone extraction? A related question asks under what circumstances fitness, in some sense, comes to demand greater investment in the procurement of a resource such as toolstone. Increased population, development of trade, and transformation of toolstone into a commodity are among the possibilities. Finally, we examine Tosawihi processing strategies in light of indications for a market economy proposed by Torrence (1986).

Technological Organization

Economic behavior involves the ways people organize themselves to accomplish specific tasks; the ways in which extraction and processing tasks were organized at Tosawihi influenced costs and benefits of the work. On the simplest political level, individuals may work alone to provide for themselves or their families, while under more complex political systems, a labor force may be paid or coerced to produce for others. We use the term "technological organization" to refer to group composition, task differentiation, and spatial task segregation involved in toolstone extraction and processing. This may be at variance with other definitions of the term (Elston et al. 1992; Kelly 1988); here we focus solely on the specifics of activity organization at Locality 36.

Data bearing on these aspects of economic behavior were recovered from various contexts. The distribution of quarry features across the landscape, strategies used in toolstone extraction, patterning of production stages within quarry pits, and the spatial relationship between quarrying and processing features and debris are all potential avenues for understanding the organization of work.

Investigation of these issues is not straightforward, however, due primarily to the nature of the archaeological record. One of the most significant factors hampering examination of technological organization at Locality 36 is lack of fine chronological control. Previously existing artifact distribution patterns may have been obscured or altered by later activity, but since few features can be dated, things associated in space may or may not be contemporaneous. For example, many reduction features are spatially discrete. At Locality 36 (cf. Chapter 10), they are concentrated along the northeastern edge of the site in the areas of highest elevation and lowest debitage density. Yet it is likely that reduction features also exist in areas near quarry features where thick debitage deposits obscure their presence and character. The debitage aprons do not yield a picture sensible to us in terms of our needs; that is, we cannot "see" individual quarrying/reduction efforts. Nor can we see quarrying efforts through time, *i.e.*, as a sequence of individual quarrying events. So, in addition to empirical archaeological data, ideas based on our own quarrying experiments form the basis for some of the following observations.

Group Composition and Size

In previous work at Tosawihi, based on evidence of activities at sites peripheral to quarry sites, we suggested that visitors were likely to have consisted of household groups (cf. Elston 1992b). Evidence from Locality 36 for activities other than quarrying are confined to a few hearths (all relatively young in age) and a small number of flake tools, ground stone fragments, and finished bifaces, together representing infrequent short-term camping; these data are silent regarding the gender, age, or size of quarrying groups. We can say only that family groups were not resident there, but probably located themselves closer to subsistence resources (food and water).

Task Differentiation

Although some quarry features at Locality 36 grew quite large over time, the physical evidence indicates that individual episodes of quarrying were conducted in relatively small workings. At any one time, quarriers probably exposed only a few square meters of bedrock. Consequently, the confined space available would have restricted to one or two the number of individuals actually working in a pit. Our extraction and processing experiments (Carambelas and Raven 1991; Elston 1992b) suggest that three or four people is the optimal group size for quarrying in a single pit, balancing the available work area (i.e., pit size) and differences in rates of extraction and processing. Two individuals could manage, albeit at a slightly slower pace; a solitary quarrier would find the going very slow. A group of three provides labor to spell the quarrier, and someone to fill and empty baskets, clear away debris, and test extracted material. Some tasks could be assigned on the basis of age (older children or elderly people could do some jobs), but a quarrying task group probably included at least two able bodied adults. If several pits were exploited simultaneously, of course, more people would have been needed.

Processing proceeds at a rate much faster than extraction. For example, in experimental extraction of moderate difficulty (Elston 1992b), one skilled flintknapper processed the extraction returns of two person days in less than one day. Quarriers could spell themselves from the exertion of quarrying by rotating processing, but the greatest processing returns probably would be achieved with the best knapper responsible for all processing. This analysis also points to a minimum work group size of three adults.

Task Segregation

Since it is difficult to move large pieces of toolstone very far, it is convenient to reduce them in or immediately adjacent the quarry pit. Even block blanks for large bifaces were not moved far from the quarry pit for reduction. On the other hand, reduction of flake blanks, partially worked bifaces, or small blocks from which less weight must be removed tended to take place at a greater distance from quarry pits. This is probably why, as we have seen in Chapter 10, a higher proportion of flake blank-based bifaces was recovered from reduction features than from quarry pits.

But, before examining the archaeological evidence for task segregation, the contemporaneity of existing patterns of features and artifacts must be considered. As noted earlier, the chronological data from Locality 36 indicates that the site was exploited over a long time and that there is some patterning to use of the place *through* time. Area C, in the southwestern part of the site, contains the oldest deposits, dating to 4000 B.P., Area B, in the northwestern part of the site was utilized most intensively between 500 and 1500 B.P., and Area A in the southeast was used over the last five hundred years. In addition, the five hearths located in the course of our excavations (in the northeastern portion of the site) yielded late radiocarbon dates and the large subsurface Feature 102 dates to 4000 B.P. (cf. Chapters 8, 9; Figure 92). There is some overlap between the time periods during which the three areas were quarried (the earliest sample recovered is, in fact, from area B, which yielded the longest span of radiocarbon dates), but there is enough patterning to suggest differential use of space through time. Thus, the patterns revealed in the course of our analyses (cf. Chapter 10) cannot be treated as static; changes in site utilization must be considered.

Reduction features at Locality 36 are densest in areas away from quarry pits, and they contain discarded bifaces made on flake blanks more often than do quarry pits. Reduction features also contain bifaces of later reduction stage, later stage debitage, and greater incidence of heat-treatment. If reduction features are considered to span all periods, then task segregation can be postulated for an unspecified period of time, but if they are considered to post-date the activity in Area C, then a change in strategies of task location is indicated.

There is some evidence to suggest that the latter is, in fact, the case. Many of the reduction features are near hearths, all of which date late in the site's history, while Feature 102, a buried quarry pit in Area C, is the oldest dated quarry feature. Biface reduction in Feature 102 differs somewhat from that in other quarry features; it exhibits a higher proportion of flake blank-based bifaces, and the distribution of distinctive opalite extracted from the feature suggests that processing (and even later stage reduction) took place in or very near the quarry pit. This may reflect a change in the amount of task segregation from the earliest (less segregated) to latest (more segregated) eras of site use.

Toolstone Extraction

In previous chapters we showed how toolstone extraction at Locality 36 focused on beds of opalite buried beneath various deposits of soil and lithic material. Two activities exemplify toolstone extraction: removal of overburden from bedrock and extraction of toolstone packages from parent material. Below, assuming quarrying is a rate maximizing procurement strategy, we propose how each of these activities may have aimed toward efficiency, and we assess our propositions in light of archaeological evidence.

To approach the economics of overburden removal, we first discuss the types of deposits overlying bedrock at Locality 36 and estimate the rates at which each can be removed. We then examine the types and depths of overlying deposits in Areas A, B, and C (cf. Figure 52) to determine the costs involved in exposing opalite at each. Based on this, we propose the order in which toolstone extraction should have proceeded in each area. Radiocarbon dates obtained from each group are compared to our proposed sequence.

To ascertain the economics of extracting toolstone packages from parent material, we discuss variability in toolstone quality and ease of extraction, estimate return rates for various qualities of toolstone, and predict which of these qualities should evidence the greatest intensity of extraction. To check the validity of our prediction, we analyze the degree to which the various qualities of stone actually were extracted.

Overburden Removal

Deposits overlying opalite bedrock at Locality 36 are a consequence of natural and cultural processes. Natural deposits include sands and gravels, eolian silts and silt loams of the present soil surface, the reddish silty clay of a well developed paleosol, and rhyolitic and kaolinitic tuffs (cf. Chapter 7). Cultural deposits created by toolstone extraction and processing are composed of chunks, shatter, chips, flakes, and hash (Elston and Dugas 1992); rejected and broken biface fragments and the tools used in extraction and processing are present as well. All these cultural items are contained within a silty or clayey soil matrix.

As archaeologists, we distinguish depositions on the basis of attributes such as texture, consistency, and structure. An attribute of concern to quarriers, however, was the difficulty involved in loosening and removing each type of deposit. Quarrying experiments (Carambelas and Raven 1991) indicate that rates for removing different materials are highly variable. Figure 112 illustrates the types of deposits present at Locality 36 and their estimated rates of excavation (cf. Elston 1992b:Table 236). Loose surficial material can be removed quickly, as can silty soils and silty quarry fill. Slower rates of excavation are associated with the clayey quarry fill and the silty clay paleosol. Tuff bedrock is associated with the slowest rates of excavation. These types of deposits are not distributed uniformly across the locality (cf. Chapter 7).

We propose that toolstone extraction should have commenced where toolstone-quality opalite could have been uncovered in the least time, based on the variable distribution of deposits and the differential rates at which they can be removed. Once the most easily extracted material was "mined out," extraction would have proceeded to areas where progressively greater effort was required to expose bedrock. To evaluate this hypothesis, we determine the deposit type, and the minimum and maximum depths of natural deposits overlying opalite bedrock, in each of three areas exposed by backhoe trenching (cf. Chapter 7). We then estimate the amount of time required to loosen and remove deposits in each area to predict the order in which toolstone extraction should have proceeded.

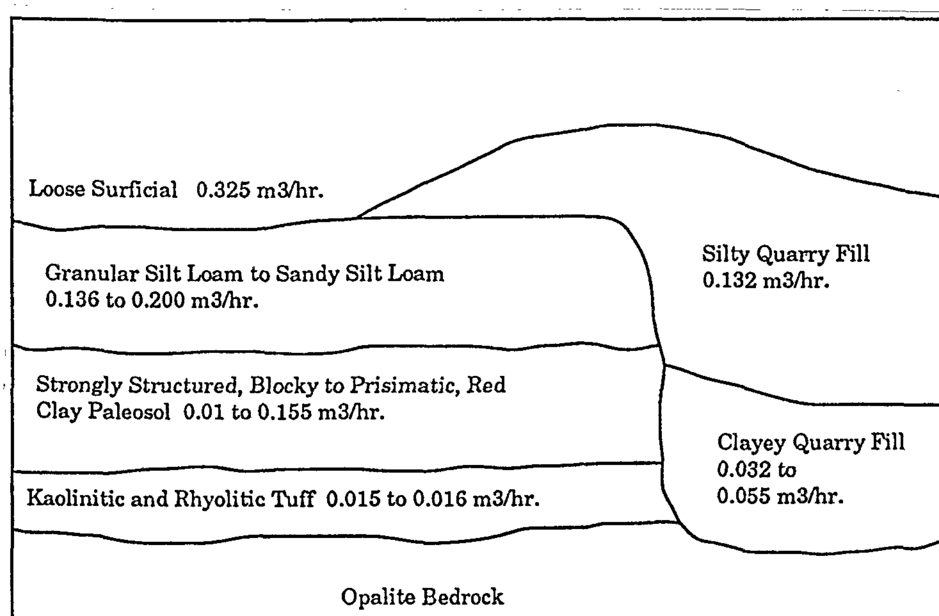


Figure 112. Deposit types and estimated rates of excavation.

Deposits Overlying Opalite Bedrock

We used the profiles presented in Chapter 8 (Figures 8.6, 8.13, and 8.21) to estimate the depth of deposits overlying bedrock. Area A contains the greatest depth of deposits, followed by Areas B and C, respectively. Area A deposits consist of a silt rich soil that ranges between 68 cm and 94 cm thick, and tuff bedrock (76 cm) or weathered bedrock and clay (22 cm). Opalite bedrock lying below these deposits grades from massive tuff to massive opalite. Area B deposits consist of a clayey silt and silty clay paleosol; the former is between 20 cm and 26 cm thick, and the latter, between 32 cm and 82 cm. Opalite bedrock is encountered beneath the paleosol. Only one deposit overlies opalite bedrock in Area C, a silt loam soil ranging between 20 cm and 28 cm thick.

Silty deposits are likely to be deeper now than they were at times in the prehistoric past. The Area A profiles (cf. Figure 60), for example, indicate that a rhyolite hammerstone was located in a non-quarry feature context some 42 cm below the present soil surface. Moreover, a bedrock ledge in the Area C profile (cf. Figure 75), now buried by 28 cm of colluvium, evidences patination and fine cracking and jointing, suggesting that the ledge was exposed at the surface in the past (cf. Chapter 8). These observations are considered when estimates for overburden removal are calculated below.

Costs of Overburden Removal

Table 64 presents data on type and depth of deposit, estimated rates of excavation, estimated time to remove each deposit, and estimated time to uncover bedrock. These are divided further into minimum and maximum estimates. Based on these data, it is evident that bedrock in Area A is the most costly to uncover, followed by Areas B and C, respectively. Minimum estimates indicate that bedrock in Area A is at least three times more costly to uncover than bedrock in Area B, and at least 17 times more costly to expose than that in Area C. Maximum estimates indicate an even profounder difference: Area A bedrock is at least four times costlier to uncover than the Area B bedrock, and upwards of 28 times more costly to uncover than the Area C bedrock. However, these estimates are predicated on the current depth of deposits overlying opalite beds.

Table 64. Excavation Rates to Opalite Bedrock at Areas A, B, and C.

	MAXIMUM OVERBURDEN REMOVAL				MINIMUM OVERBURDEN REMOVAL			
Area	Deposit Type	Depth of Cover (m)	Rate of Excavation (m^3/hour)	Removal Time (hour)	Deposit Type	Depth of Cover (m)	Rate of Excavation (m^3/hour)	Removal Time (hour)
A	SSL	.94	.133- .20	6.912-4.70	SL	.68	.136- .20	5.0-3.40
	TB	.76	.015- .016	50.667-47.5	WB/C	.22	.015- .016	14.667-13.75
	total			57.579-52.2				19.667-17.15
B	CS	.26	.136- .20	1.912-1.30	CS	.2	.136- .20	1.471-1.0
	CP	.82	.068- .07	12.059-11.714	CP	.32	.068- .07	4.706-4.571
	total			13.971-13.014				6.177-5.571
C	SL	.28	.136- .20	2.059-1.40	SL	.2	.136- .20	1.471-1.0
	total			2.059-1.40				1.471-1.0

CP=Clayey Paleosol SSL=Sandy Silt Loam TB=Tuff Bedrock
CS=Clayey Silt SL=Silt Loam WB/C=Weather Bedrock/Clay

Approximately 42 cm of silt have been deposited in Area A since the discard of a hammerstone in a non-quarry feature context, and approximately 28 cm of silt have accumulated over the bedrock ledge in Area C. Assuming the hammerstone was deposited on a working surface away from a quarry feature, the amount of deposit to be removed by quarriers is reduced by 44.7 percent, leaving approximately 52 cm of silty soil. However, 52 fewer centimeters of silt to remove at this place would reduce the total estimated amount of time to reach bedrock by only 5 to 7 percent. On the other hand, 28 fewer centimeters of silt in Area C would reduce the amount of time required to reach bedrock by 100 percent. These observations support our argument that bedrock in Area A was the most costly to expose, and that in Area C, least costly.

Our hypothesis asserts a relationship between the variable cost of exposing bedrock and the placement and development of quarry features. Specifically, we expect that toolstone extraction commenced where the costs of uncovering bedrock were lowest (Area C), followed by extraction at places increasingly more costly to uncover (Area B, then Area A). If this is true, radiocarbon dates from Area C should be generally older than those from Area B, which in turn should be generally older than those from Area A.

The 27 radiocarbon dates obtained from quarry features at Areas A, B, and C are plotted in Figure 79. A general trend is perceptible in this figure which seems to satisfy our expectations. Dates associated with Area A are relatively recent, while those associated with Areas B and C are progressively older. A notable exception to our prediction consists of a relatively old date at Area B.

Five pre-3500 B.P. radiocarbon dates were obtained from Locality 36. Four were recovered from Area C, and one (4090±100) from Area B. The date from Area B apparently constitutes a deviation from our expectation. In order to determine if this date differs significantly from those of Area C, we compared the dates between the two areas statistically (cf. Thomas 1986:249-251). Our results (Table 65) indicate that in only two instances are Area C dates significantly different from the Area B date. This prompts us to suggest that, although limited evidence of early quarrying is present in Area B, most toolstone extraction was conducted initially in the most cost effective area, Area C.

Table 65. Comparison of Pre-3500 B. P. Radiocarbon Dates Between Areas B and C.

Area B		Area C	
Reference No.	Date	Reference No.	Date
2599-220-53	4090±100	2599-159-6	3890±70
		2599-161-8	3830±80
		2599-160-7	3810±60*
		2599-162-9	3670±90*

*Significant at 0.05 level

Procuring Toolstone Packages from Bedrock

Once deposits overlying bedrock were removed, quarriers extracted toolstone packages from parent material. The features they created and the extraction methods they used were affected by bedrock geology; the toolstone quality of bedrock motivated quarriers to focus efforts in particular places (cf Chapter 9). We presume that these efforts tended toward rate maximization. A similar presumption was evaluated by Torrence (1986), who also recognized the effects of geology on toolstone extraction. The methods we use to evaluate our hypothesis are similar to those used to evaluate the efficiency of toolstone extraction at the Sta Nychia and Demenegaki obsidian quarries (Torrence 1986:171-18). Below, we briefly review the toolstone quality typology introduced in Chapter 9, estimate extraction return rates for various qualities of toolstone, and assess the extent of extraction for each quality as observed in backhoe trenches at Locality 36.

Variation in Toolstone Quality

As toolstone, opalite ranges from poor quality material found in poorly silicified or highly fractured beds to above average quality material located in massive, relatively homogeneous beds. The ease with which toolstone can be extracted from bedrock is related inversely to its quality; lower quality toolstone is easier to extract than high quality toolstone (cf. Chapter 9). One might think that quarriers would ignore the poorest material in favor of the best, unless good material were so massively emplaced that it could not be extracted; in that case, quarriers should ignore it as well. But, clearly, toolstone *was* extracted; what we seek are quantitative means of describing the trade-offs between toolstone quality and ease of extraction. Then we can ascertain which qualities of toolstone provided the most efficient extraction returns per unit of time or effort. Quarrying experiments conducted at Tosawihi yielded data that allow generation of such estimates.

Variation in Extraction Return Rates

Four of five quarrying experiments attempted to extract toolstone packages from buried bedrock. One attempt focused on weathered, poor quality material, a second on massive, high quality material, a third on average material, and a fourth on material grading from below average to average quality. Toolstone packages were assessed by a flintknapper in order to determine their suitability for processing. As a consequence, numerical data generated by these experiments (cf. Carambelas and Raven 1991; Elston 1992b) allow us to estimate a net extraction return rate (*neRr*) for the different qualities of stone that we attempted to extract (Table 66). The *neRr* is simply the rate at which a mass of stone suitable for processing can be extracted in some unit of time (Elston 1992b). That is,

$neRr = neR_i / T_i$ where

neR_i = total net return of unrejected toolstone (gm) obtained in excavation event i

T_i = total amount of time (min.) spent in excavation event i

Table 66. Estimated *neRr* for Various Toolstone Quality Rankings.

Experiment Number	Toolstone Quality Ranking	Total Time of Excavation Event (min.)	Total Net Extraction Return (gm)	Net Extraction Return Rate (gm/min.)
1	Poor	300.0	0	0
2	Above Average	240.0	0	0
3*	Average	360.0	?	?
4	Below Average to Average	820.0	53,600.0	65.37

* 19,300.0 grams of toolstone obtained during experiment but not assessed by knapper

Our data do not allow estimates for each quality of toolstone. Nevertheless, we can provide estimates for the two extremes, and for a point somewhere between. A *neRr* of 0 is estimated for poor quality material, since the stone was too fractured to produce toolstone packages of an acceptable size. Also, poor quality stone may not produce tools even if packages of sufficient size are obtained because the material is so poorly silicified that it cannot be flaked. A *neRr* of 0 also is estimated for above average quality toolstone. This massive, homogenous material resisted hammerstones, and its lack of fractures disallowed the use of wedges to force chunks from parent material. The highest *neRr* (65.37 gm/min.) is estimated for opalite that grades from below average to average in quality. Fractures in the bedrock facilitated toolstone removal from parent material, yet the quality of the stone allowed flake propagation and tool production.

One quarrying experiment was conducted on a bed of opalite assessed as average in quality; a gross return of 19,330.0 grams was realized, but the potential of the material for processing was not assessed. No experiment was conducted on opalite judged to be below average in quality. Consequently, we offer *neRr* estimates for neither average nor below average quality stone. Nevertheless, we suspect the *neRr* for below average to average quality toolstone either approaches or lies just beyond the point at which extraction efforts realized diminishing returns. At the very least we can estimate with confidence that below average and average quality stone has a *neRr* that is relatively greater than poor or above average quality stone. With these estimates in mind we can anticipate the interaction between toolstone quality and degree of extraction.

Our hypothesis for efficient toolstone extraction suggests that quarriers should have focused effort on bedrock that provided the best *neRr*. Therefore, we expect that toolstone extraction from beds that are either poor or above average in quality should have been less frequent than toolstone extraction from beds of below average to average quality. Toward evaluating this hypothesis, we examine the intensity of extraction in opalite of various qualities. Differences in the degree of extraction between below average, below average to average, and average quality opalite remains to be investigated.

Intensity of Toolstone Extraction

The present shape of quarry features and opalite bedrock is a consequence of at least 4,000 years of intermittent toolstone extraction. Here we estimate the intensity with which different qualities of stone were extracted from bedrock. Intensity of extraction is simply a measure of the extent to which a particular deposit was quarried. Measures of intensity of extraction can be calculated in a number of ways; ours is a subjective measure (cf. Torrence 1986:171, 178), outlined below.

Figure 113 illustrates how we estimated intensity of extraction. First, we assumed that each trench wall serves as a two dimensional line transect, sampling variability in toolstone quality and amount of toolstone removed. Using the bedrock quality maps drafted by a lithics specialist (cf. Figure 85a), we estimated the position of each quality grade and plotted its boundaries on the profiles of trenches 1, 2, 3, 4, 5, 7, 8, 10, and 11 (cf. Figures 8.4, 8.6, 8.9, 8.12, 8.13, 8.17, 8.18, 8.20, and 8.21). For example, the entire length of bedrock exposed in Figure 113 is 37 m; of this, approximately 8.5 m is poor quality toolstone, while below average and average quality bedrock account for an estimated 15 m and 13.5 m, respectively.

Second, from the unexcavated portions of bedrock and tuff illustrated in the profiles, we estimated the position of the original, unquarried bedrock surface relative to the present quarried surface, and calculated the area between the two surfaces using a digitizer. Assuming that the area between the two surfaces resulted from toolstone extraction, and that the stone removed was of the same quality as that remaining on the quarried bedrock face, two measures were obtained: the estimated length of bedrock exposed in the trench and the estimated area excavated from the bedrock.

Third, a measure for the intensity of extraction was obtained by dividing the total estimated area excavated from each quality grade (A) by the total estimated length of that quality

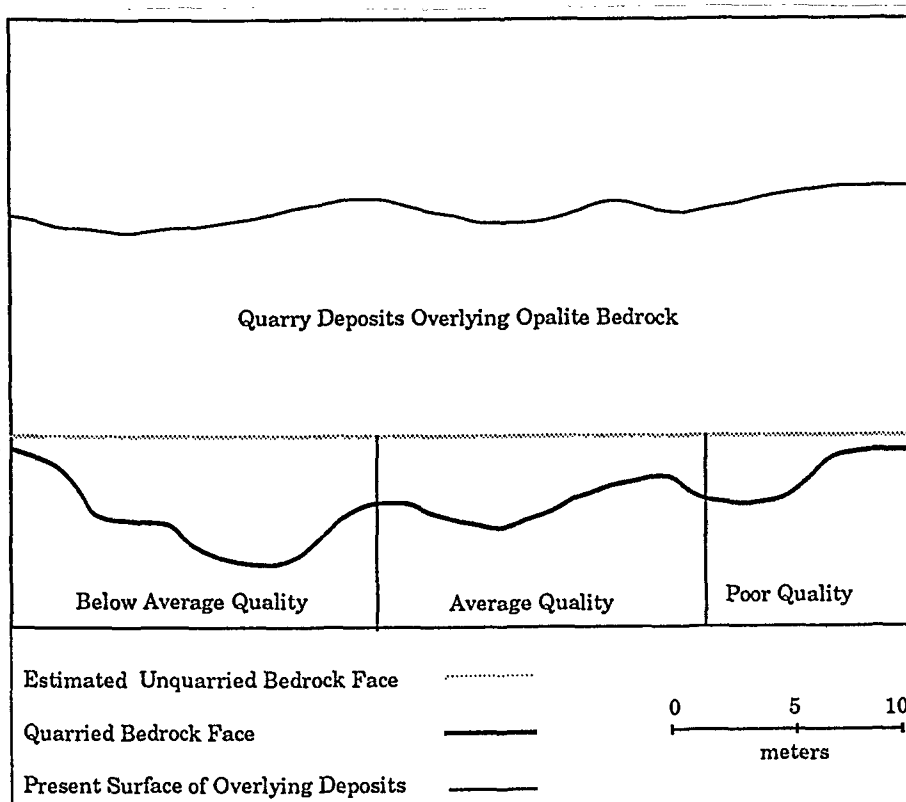


Figure 113. Schematic of estimated unquarried and quarried bedrock faces.

grade (L). The quotient represents the average amount of area removed per meter length of that quality grade. Table 67 presents estimated length and area measurements for opalite bedrock observed and rated; quotients for each quality grade are plotted in Figure 114.

Table 67. Estimated Length and Estimated Area Excavated from Bedrock.

Toolstone Quality Ranking	Location	Estimated Length of Bedrock Observed in Profile (m)	Estimated Area Excavated from Bedrock Observed in Profile (m^2)
Tuff	Trench 1	7.400	0.000
	Trench 5	0.342	0.000
	Trench 10	0.859	0.031
	Trench 11	2.125	0.000
	Trench 3	8.330	1.585
	Trench 8	5.200	0.647
Totals		**24.256**	**2.263**
Poor	Trench 2	6.650	0.000
	Trench 7	5.592	0.000
	Trench 11	2.250	0.083
	Trench 8	3.700	0.803
Totals		**18.192**	**0.886**
Poor to Below Average	Trench 10	1.503	0.319
	Trench 11	2.250	0.176
Totals		**3.753**	**0.495**
Below Average	Trench 2	1.800	0.004
	Trench 7	1.850	0.019
	Trench 4	9.600	1.841
	Trench 5	3.227	0.477
	Trench 10	0.859	0.069
	Trench 11	0.875	0.005
	Trench 3	1.700	1.445
Totals		**19.911**	**3.860**
Below Average to Average	Trench 4	8.950	0.500
	Trench 11	7.500	0.377
Totals		**16.450**	**0.877**
Average	Trench 1	11.200	2.489
	Trench 2	7.950	1.510
	Trench 7	5.958	1.167
	Trench 4	7.650	0.858
	Trench 5	11.131	3.883
	Trench 10	4.079	0.744
	Trench 5	6.500	1.073
Totals		**54.468**	**11.724**
Below Average To Above Average	Trench 3	0.971	0.299
Totals		**0.971**	**0.299**
Above Average	Trench 3	6.199	0.000
Totals		**6.199**	**0.000**

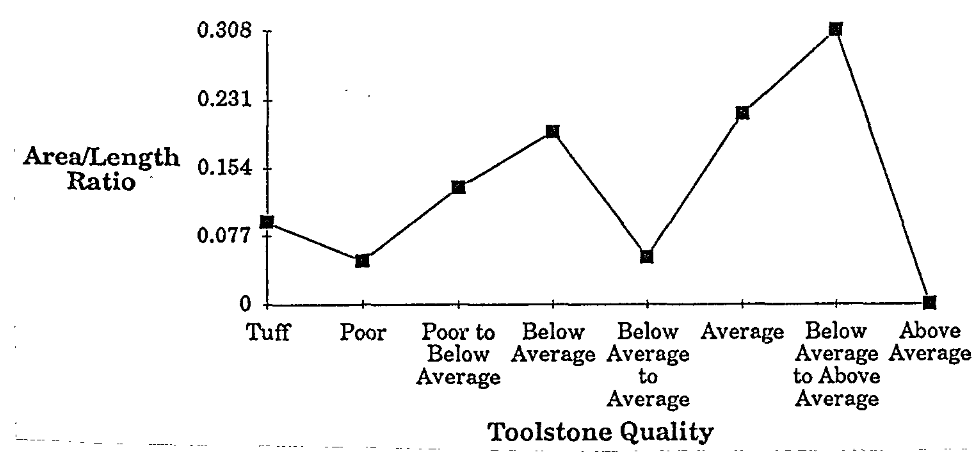


Figure 114. Area excavated per length of bedrock.

As anticipated, poor and above average quality opalite was not utilized or was underutilized compared to other qualities of bedrock (with the exception of below average to average quality toolstone, discussed below). Above average opalite apparently was not utilized. However, this material was found only in a small band (Trench 3) at the very back of an adit (Feature 41). The opalite in the adit probably was both impenetrable and extremely difficult to reach. Poor quality stone apparently received some attention, but much less than other qualities of stone.

An obvious exception to our prediction is evident. The estimated *neRr* for below average to average quality opalite is notably different from the *neRr* for poor and above average quality bedrock, but the intensity of extraction of this stone is not much different from that of poor quality stone. At this point, we surmise that our estimated *neRr* for this quality of stone represents either a rate lower than the below average and the average quality stone, or that our assessment of bedrock quality was less accurate than for the two extremes. The latter seems more plausible given the complex nature of the bedrock. In summary, bedrock exposed at Locality 36 leads us to conclude that most toolstone extraction was conditioned by the potential net returns quarriers could achieve from the various qualities of toolstone.

Toolstone Processing

The focus of opalite processing at Locality 36 was biface production. We previously addressed production efficiency in terms of biface transport costs (cf. Elston 1992b); based on distributions of bifaces across the project area, we decided that transport cost was the factor most influencing the extent to which bifaces were reduced before export from the quarry vicinity. Our prior work at sites peripheral to the Quarries proper (Elston and Raven 1992), indicated that the most commonly exported artifact form was a mid- to late Stage 3 heat-treated biface. Experimental replication studies suggested that in this form and at this point in the reduction sequence, the bulk of waste mass had been removed (Figure 115), and the greatest risk of manufacture failure had been avoided.

In Chapter 5 we showed that bifaces produced at Locality 36 and other Tosawihi *quarrying* sites were transported away from those sites in a similar form (un-heat-treated, early Stage 3), while bifaces exported from the Tosawihi production area as a whole were advanced farther along the reduction sequence (heat-treated mid- to late Stage 3). This suggests that support camps for Locality 36 quarriers were located away from the quarry area (nearer water and food sources) and that bifaces probably were reduced there before export.

But processing efficiency can be examined from other perspectives. Torrence (1986) defines four aspects of production around which efficiency of production can be evaluated: sophistication, simplification, standardization, and specialization. This scheme considers the ways in which processing is accomplished and the design of the finished product. Since only the production end of the lithic procurement, processing, and tool use system can be examined at Locality 36, we rely to some degree on general data to evaluate these aspects of production efficiency.

Toolkit Composition

One aspect of production efficiency involves the configuration of the tool repertoire. Torrence (1986) argues that single purpose toolkits are sophisticated and more efficient than

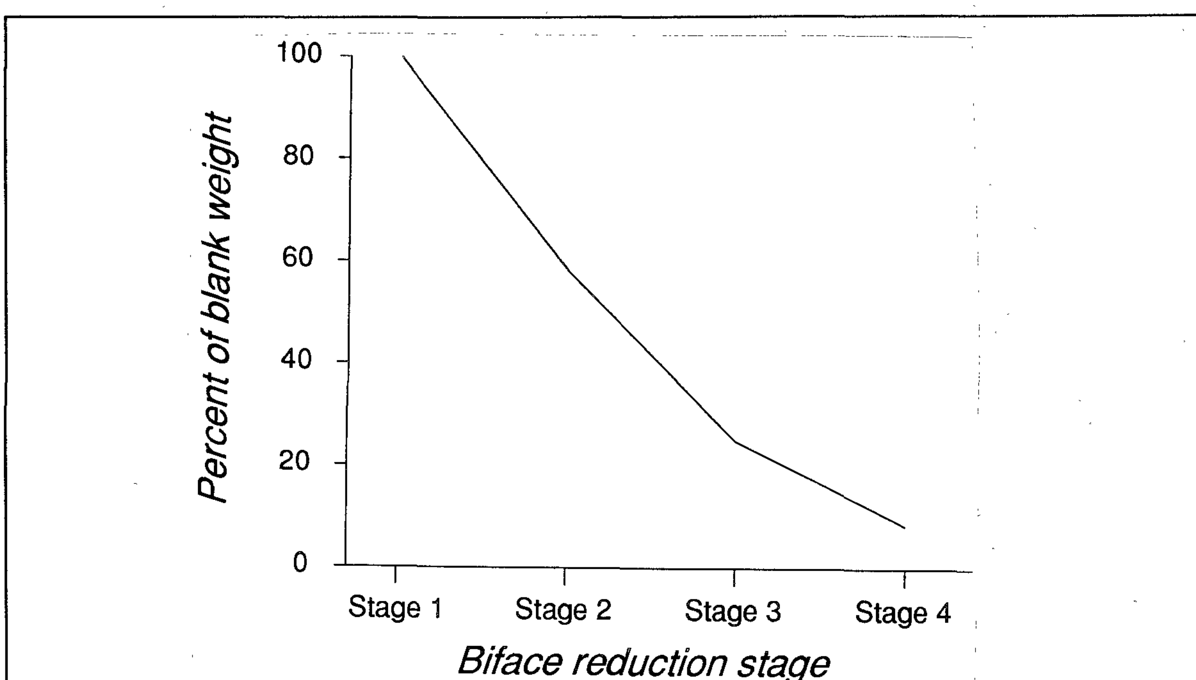


Figure 115. Experimental replication data showing change in biface weight at stages in the reduction sequence.

generalized ones and that, therefore, one criterion for recognizing production efficiency is the presence of specialized toolkits. There is considerable evidence for the prehistoric use of specialized toolkits in the Great Basin; caches of hunting tools, sewing kits, flint-knapping kits, duck decoy repair kits, etc., recovered from dry contexts (often in cave deposits; Hester 1974; Heizer and Kreiger 1956; Thomas 1985; Ingbar 1985) attest to the concept of specialized toolkits, but some bundles are composed of multiple, specific toolkits (Loutham 1990) that may have been transported as units. Historic hunter-gatherers of the Great Basin often participated in foraging trips in which a wide variety of resources was sought (Downs 1966; Thomas, Pendleton, and Cappanari 1986) and for which various tools would be needed. In these situations, mobile foragers might find it most efficient to carry a flexible toolkit composed of a very few, multipurpose items, such a kit being lighter in weight and thus easier to transport; alternatively, the make-up of a toolkit might vary depending on the purpose of the trip.

At Locality 36, the only tool for which we have clear evidence of manufacture is the biface. Bifaces exported from Tosawihi were intended primarily as bifacial knives (Ataman and Bloomer 1990, 1992). Bifacial knives are effective, multipurpose tools and can be resharpened easily without much risk of breakage. The ubiquitous distribution of bifaces at Great Basin archaeological sites indicates that before the introduction of metal tools, the biface may have been one of the most important elements of many prehistoric toolkits.

Production Standardization

Production standardization is another criterion which can be used to evaluate production efficiency. The bifaces produced at Locality 36 are homogeneous in form (cf. Chapter 5). Most pieces in the assemblage are of the same stage (early Stage 3), few are heat-treated, and size variation is minimal. Compared to other Tosawihi sites, the pieces in the biface assemblage from Locality 36 exhibit a lower range of variation in every dimension, even though the site was used for at least four thousand years. Thus, in terms of product standardization, our data suggests that processing at Locality 36 was organized in a cost effective way.

Technological Simplification

Simplification of both technological procedures and tool design, which may reduce the number of manufacturing stages, creates efficiency by requiring less production time. However, decisions to use particular techniques, such as using flakes rather than blocks as biface blanks, are influenced by factors not easily observed in the archaeological record. In the example at hand, flake blanks may be preferred when bedrock structure allows flakes to be detached easily or when massive blocks from which flake blanks can be struck can be removed easily.

In terms of tool design, bifaces are rather simple; the formal differences between most bifaces often are due to raw material variation, although certain small specimens serve as preforms for projectile points which may convey ethnic, stylistic, and functional information.

Differences in manufacturing techniques can be recognized most readily at production sites such as Locality 36. Square edge and end-thinning techniques were found in many parts of the site (cf. Chapters 5,10), so it is likely that they were components of the technological repertoire throughout the exploitation of the quarry. These two techniques are represented in similar proportions in a variety of contexts. It is more difficult to examine changes in the proportions of flake blank-based bifaces through time. This type of biface blank was most common in the area of the site exploited earliest (Feature 102 in Area C), and slightly less common in the reduction features excavated near the Late Archaic hearths. Flake blank-based bifaces are least common in the quarry pits of Areas A and B, which date primarily from 1500 B.P to the present. It is likely that, while this was never a dominant technique, it was practiced to some extent throughout site history. Proportional differences between contexts are not great, and we have insufficient chronological control to determine whether the use of these more efficient techniques increased or decreased through time.

Production Specialization

Specialization, in terms of access to resources, exclusive reliance on high quality raw material, and organization of labor is another aspect of production efficiency (Arnold 1985; Seeman 1985). There are many raw material sources in the greater Tosawihi vicinity and control of access would have been difficult to effect. Ethnographic accounts provide no indication that such control over toolstone sources existed, although family-owned nut groves and other property are documented historically (Downs 1966; Fowler 1986).

The question of craft-specialization is also difficult to evaluate. Historic accounts of craft specialists exist, such as arrow makers (Fowler and Matley 1979, Figure 57) and commercial basket weavers (d'Azevedo 1986), but it is possible that such accounts refer to remnant knowledge by older people who remembered shared craft skills or who developed them in response to white demand. If specialist knappers existed, it is unlikely they possessed exclusive skills; rather, they probably were more skilled than others in their group and worked faster, with a higher success rate.

The quarriers at Locality 36 do not seem to have concentrated on the exploitation of the highest quality material (cf. Chapter 9). It seems to have been more efficient to exploit medium quality material which was less costly to extract, and could be worked effectively, rather than aim for higher quality material that was more difficult to extract. The savings achieved by working more uniform, high quality material, with less discard of material flaw-induced failures appears not to have offset the greater difficulty of extraction.

Thus, while many aspects of toolstone processing at Locality 36 may have been cost-effective, evaluation of all the factors involved is problematic. The technology was simple and probably was not practiced exclusively by specialists. Biface design was standardized, and bifaces were the most effective tool form for performing the widest number of tasks.

Summary and Discussion

If our previous conclusions are correct (cf. Elston and Raven 1992) and no important factors remain undetected, people probably visited the Tosawihi Quarries with their families, and, if their visits lasted more than a few days, some members of the group undoubtedly gathered food for the group. Quarrying was done by a minimum of three adults. Children may have assisted either quarrying or food gathering. The extent to which task differentiation and segregation were features of quarrying and biface production at Locality 36 may have changed through time.

Our experiential and circumstantial evidence suggests a likely scenario:

Extraction of toolstone packages from opalite bedrock at Locality 36 commenced no later than 4,000 B.P. The task involved two costly procedures: removing overburden from bedrock opalite, then hammering and/or wedging usable toolstone packages from the parent material. The archaeological record of both activities supports the notion that quarriers attempted to keep costs low and return rates high.

Overburden removal involved the break-up and dislocation of deposits of various thicknesses and levels of extraction difficulty. Stratigraphy and radiocarbon dates from each of three areas suggest that quarrying commenced where overburden removal was easiest and subsequently proceeded into areas where it became increasingly more costly. Thus, over the four thousand years of intermittent use, quarriers kept extraction costs low at Locality 36 by focusing on quarryable bedrock that could be reached with the least effort.

Extraction of toolstone packages from bedrock involved wedging and hammering blocks of opalite from parent material; structural features of the bedrock facilitated removal, while massiveness of bedrock inhibited it. The archaeological record created by this procedure suggests that quarriers attempted to keep toolstone return rates high by focusing on areas of bedrock that returned the greatest amount of usable toolstone per unit of time invested, and that they ignored *areas offering lower return rates.*

For the period of earliest exploitation (ca. 4000 b.p.), there is no evidence for task segregation; processing took place in or adjacent quarry pits. The use of flakes as biface blanks was more common than in later periods, possibly because the toolstone in Trench 3 (from which most of the early dates derive) occurred optimally, deposited in a narrow band of high quality material from which flakes could be detached easily. In contrast to later periods, even later stage reduction took place immediately around the pit, and less heat-treatment is evident. Sites away from the quarries contain time-diagnostic artifacts from this period, but there is little to suggest that early quarriers camped at Locality 36. This implies short visits by small numbers of people or several family groups working in separated areas.

On the other end of the time scale, if we assume that reduction features near late-dated hearths are also late, we must conclude a change in technological organization. Under this scenario, later stage reduction and heat-treatment, as well as flake blank-based biface reduction, took place in these reduction features, while biface reduction near the pits was more block-based and earlier in stage. In addition, hearths and the few flake tools and ground stone fragments also are located in these areas.

What could cause this change? In our previous work at Tosawihi, we noted an *intensification* of production toward the end of the Archaic period. Segregation *of activities, implied* task differentiation, and evidence for some ancillary activities at Locality 36 during this period could be explained by such intensification. Larger groups, perhaps staying for longer visits, spread their activities over a larger portion of the area and left more evidence behind.

Some of this is speculative, notably that undated reduction features near late-Archaic hearths also date to the end of the Archaic. Nonetheless, the scenario offered here provides a model which will be useful for comparison as data from other Great Basin quarries become available.

Chapter 13

THE VIEW FROM LOCALITY 36: RECAPITULATION AND PROSPECTUS

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This final chapter summarizes our understanding of Locality 36, but, as we promised in the Epilogue of Part One of this series of reports (Elston and Raven 1992), we also summarize the findings of all our work at Tosawihi Quarries and evaluate its archaeological significance.

The Place of Tosawihi Quarries in Prehistory

The importance of Tosawihi to prehistoric foragers is reflected in the size of the quarry complex, the length of time that the quarries were utilized, and the regional distribution of the material procured from them (cf. Chapter 1). Tosawihi constitutes one of the largest prehistoric bedrock quarry complexes in North America. Encompassing 800 acres, with at least 1,000 more acres of ancillary processing sites, the Tosawihi Quarries are comparable in size to quarry complexes found at Flint Ridge, Ohio (Holmes 1919), Spanish Diggings, Oklahoma (Bryan 1950), Alibates, Texas (Bryan 1950), Knife River Flint, North Dakota (Ahler 1986), and Allendale, South Carolina (Goodyear and Charles 1984). Chipped stone artifacts produced from Tosawihi opalite indicate that the material was utilized from Clovis times to the present, a period of about 11,000 years. Moreover, the Tosawihi Quarries supplied material for trade over great distances; artifacts produced from Tosawihi opalite have been observed at sites 175 km away.

Recent ethnographic work among Tosawihi Shoshone, who presently live in Nevada, Idaho, and Utah, indicates that the Quarries were economically, socially, and spiritually significant to historic users of the opalite deposits, and that trade of opalite in the historic period may have been more extensive than can be ascertained by the prehistoric archaeological evidence at the quarries.

A Deductive Theoretical Approach to Lithic Procurement

The magnitude of the archaeological record at Tosawihi Quarries demanded some means to focus inquiry. A purely empirical approach would not have indicated or ranked relevant data classes, methods of data collection, or techniques of data analysis; consequently, our research would have been more tentative and probably much less informative than it has turned out to be. As it happened, some of us already were thinking about subsistence strategies and resource procurement in terms of microeconomics and evolutionary ecology (Raven and Elston 1989; Elston and Budy 1990), both of which predict behavior on the basis of benefits and costs. Study of the Tosawihi phenomenon afforded an opportunity to develop these ideas with regard to lithic procurement, which we have shown to be well suited for cost-benefit analysis.

Taphonomy is less problematic for cost-benefit analyses of lithic procurement than of organic resource acquisition because lithic procurement often leaves large quantities of non-perishable byproducts that unambiguously mark localities of toolstone extraction, processing, and manufacturing. While the locations of toolstone sources remain constant through time (but cf. LeBlanc 1991:268-277), cultural and technological factors affecting the benefit/cost equation were free to vary. Thus, we assumed that much of the archaeological variability observed at Tosawihi reflects variability in human behavior rather than taphonomy.

Our model of lithic production, based on economic theory and data derived from experimental quarrying and biface reduction, permitted a highly deductive approach to the archaeology of Tosawihi Quarries. We asked how people would have behaved at Tosawihi had they made purely economic decisions, with payoffs in risk reduction, personal survival, or fitness. Yet, as our studies have demonstrated, application of the model takes us far beyond mere definition of Tosawihi as a special purpose site with economic importance.

The structure of Tosawihi Quarries (distribution and content of extraction, processing, and base camp sites) is explained in terms of the economics of procuring and transporting toolstone. *Tosawihi quarriers preferred efficient solutions to economic problems involving indirect costs* (i.e., by strategic use of the landscape), but they sought to increase net toolstone returns through judicious quarrying strategies. We have few data with which to apply the economic model outside the production sphere around Tosawihi. Nevertheless, it begins to illuminate other aspects of prehistoric economic behavior at a regional scale. For example, including visits to Tosawihi Quarries in the seasonal round must have incurred opportunity costs. Thinking about how prehistoric people could have minimized these, we have begun to confront labor organization, technological organization, mobility, scheduling, and positioning as components of larger subsistence strategies, elements that figure in current middle range theory. In the final analysis, however, our focus on economic relationships and fitness as ultimate causes of human behavior seeks to subsume middle range explanations of variability.

The task of modeling the economics of lithic procurement is challenging, and numerous theoretical issues remain to be worked out. For example, we are discontent with warranting arguments based mainly on risk and would prefer a more direct relationship with fitness. Finding one will require resolution of appropriate currencies to employ in the model. Costs expressed as time and energy are straightforward, but utility expressed as grams of material or as functionality are only approximations of increased efficiency in the capture and processing of food resources, the real utility gained from use of stone tools. We also must reduce our present uncertainty over when it is better to frame expectations in terms of cost minimization (efficiency) and when in terms of maximization of net returns (profit). We ultimately may be constrained by what is visible in the archaeological record.

Although we wish to emphasize our approach as deductive, we do not want to leave the impression that the model has been applied in a fully developed form from the outset. On the contrary, we began to study Tosawihi with a few basic ideas that, for the most part, were operationalized only vaguely. We have revised our schemes continuously as the work progressed, and still regard our model rudimentary in its present form.

Lithic Procurement and Processing at Locality 36

The most basic questions posed in our investigations at Locality 36 centered on how opalite was extracted, on how extracted opalite was processed, and on non-quarrying activities that may have occurred in conjunction with opalite extraction. We found that, with the exception of a few artifacts and features not directly attributable to quarrying activity including hearths and millingstone fragments), toolstone extraction and early stage processing were the focus of activity at Locality 36 (cf. Chapters 4, 5). Most flake tools in the assemblage were produced and used expediently and it is likely that they were used primarily in the manufacture and maintenance of quarrying tools. The few projectile points may or may not be connected to quarrying; sourcing and hydration data are consistent with patterns observed previously (cf. Chapter 5).

Experimental Quarrying and Processing

The size and form of toolstone packages extracted from bedrock limited the size and form of tools produced. Given that the production of bifaces of a certain size, shape, and stage was the primary goal of lithic procurement at Locality 36 (cf. Chapter 5), we employed data generated from actualistic quarrying and replication experiments to estimate the minimum size of toolstone packages needed to produce such artifacts. We observed that, at the very least, toolstone packages more than three times the weight of a typical Stage 3 biface would have been required. Toolstone packages not meeting this minimum size were likely to be discarded, and certain areas of the bedrock may not have been quarried because potential packages were too small.

Actualistic quarrying and replication experiments generated data to model the time and effort required to extract and process toolstone (cf. Chapter 12; Elston 1992b). We used experimental quarrying data to estimate the time required to remove overburden from toolstone beds, and to estimate return rates for different qualities of stone. Temporal variation in quarrying activity between Areas A, B, and C can be accounted for, at least in part, by the variable amount of time required to reach toolstone beds; the estimated costs of overburden removal increase from Area C to Area B to Area A, and this sequence is paralleled by radiocarbon dates progressing from oldest to youngest. Extraction of toolstone from opalite bedrock, once overburden had been removed, was contingent on the quality of the bedrock and the rate at which toolstone packages could be removed; quarriers apparently focused most of their efforts on areas of bedrock that provided the most usable toolstone per unit of time spent in extraction.

Data generated by replication experiments, combined with that derived from quarrying experiments, allowed us to estimate much of the total costs in time and effort of lithic procurement at Tosawihi, and to examine where processing was done best (Elston 1992b). Experimental bifaces similar to those observed at Tosawihi require approximately one hour per biface to produce, with "processing" accounting for 18 percent of the time and "extraction" comprising the other 82 percent. Because up to 95 percent of the extracted toolstone package mass was removed in processing (cf. Elston 1992b), in most instances it paid quarriers to process toolstone to some degree prior to its export.

Biface Production

Bifaces were the intended product of extraction and processing efforts at Locality 36; there is no evidence for flake production (except for biface blank production) represented in the technological repertoire. In fact, the cores and modified chunks present in the assemblage probably are by-products of early stage biface processing. Breakage and thinning failure were equally responsible for biface discard, a pattern quite different from that at non-quarry sites, where breakage accounts for almost all biface discard.

Locality 36 bifaces were derived from flake blank and block cores, almost exclusively of raw material occurring on-site. Mass reduction, blank preparation, and early biface thinning were the most frequent stages of reduction undertaken; late bifacial thinning and tool finishing were relatively rare. Blank preparation and early biface thinning occurred surprisingly often in quarry pit contexts. It is *not* surprising, however, that heat-treatment of opalite (undertaken to increase raw material workability) is less common than at non-quarry Tosawihi sites, since the technique is associated most often with later stage reduction.

Using a simple simulation model (cf. Chapter 5), we determined that bifaces were removed from Locality 36 in early Stage 3, a form somewhat earlier than we have proposed for export from non-quarry sites (mid to late Stage 3). Based on this difference in export product and on the non-residential character of the site, we suggested that bifaces produced at Locality 36 were reduced initially at the quarries, then removed to nearby camp/processing sites where they were reduced further and often heat-treated before export from the Tosawihi area.

A number of specialized reduction techniques, such as the use of flake and block blanks, end-thinning, and thinning from a square edge, were noted in the course of our studies. The use of these techniques appears not temporally variable, but related to stages of production executed at the site and to the nature of the particular biface blank employed. Whether biface production at Locality 36 may have been conducted by craft specialists remains uncertain; standardized biface size and morphology suggest specialized production, but they are not conclusive hallmarks of craft specialization.

Variation in Bedrock Setting and Quarrying Strategy

Our investigations of toolstone extraction revealed that bedrock topography (cf. Chapter 9) affected the way in which toolstone packages were removed from parent material at Locality 36, and that it influenced decisions to exploit certain areas of the bedrock. Factors comprising bedrock topography include location and inclination of opalite beds, variation in bedrock structure, quality and ease of extraction of opalite bedrock, and size and shape of packages procured from parent material.

Beds of opalite are not distributed evenly across the locality, owing to differential emplacement of silica throughout the underlying bed of tuff (cf. Chapter 7); backhoe trenching revealed that placement of quarry features was predicated on this distribution (cf. Chapter 9). Trenches excavated through quarry features exposed toolstone-quality beds of opalite, while trenches excavated in non-quarry feature contexts uncovered unsilicified beds of tuff, underscoring the significance of pre-extraction prospecting.

The inclination of opalite beds relative to the surface from which quarriers worked, or what we have termed the "bedrock setting" (cf. Chapters 8 and 9), determined the type of quarry feature that was produced. Adits formed as quarriers pursued toolstone on beds that tended toward or intersected the surface from which they worked (a Type I or II setting; cf. Chapter 7:Figure 54). Quarry features in Area C (cf. Chapter 7:Figure 52) demonstrate this relationship. Pits and scoured surfaces formed as quarriers excavated stone from beds nearly horizontal to the working surface (Type III); each quarry feature in Area A and many in Area B are consequences of this bedrock setting. Features exhibiting attributes of both pits and adits were noted in bedrock settings intermediate between Type II and Type III, as in the southern and the western portions of Area B.

Toolstone extraction from parent material was facilitated or inhibited by the structural features of opalite beds (cf. Chapter 9). Fractures, joints, and tuff stringers and pockets assist separation of large chunks of stone from parent material; quarriers succeeded in removing toolstone packages from bedrock by placing wedges into these features or by hammering directly on them. On the other hand, massive opalite is nearly free of structural features; wedges could not be forced into the rock, and hammering directly upon it was futile. Across much of the bedrock exposed by the backhoe, we observed that quarry features are located in areas where structural features are well developed, and that they tend to terminate where bedrock becomes massive.

An inverse relationship between the toolstone quality of opalite and the ease with which it could be extracted was demonstrated: as opalite quality grades from poor to above average, the ease with which it can be extracted grades from relenting to obstinate (cf. Chapter 9). Tosawihi quarriers appear to have traded quality for ease of extraction in attempting to return the most usable stone per unit of time invested (cf. Chapter 12).

Artifact and Feature Distributions

The study of artifact distributions at Locality 36 reveals patterns at different levels: within artifact classes, between them, and at varying spatial scales (*e.g.*, across the entire locality, between feature contexts; cf. Chapter 10). Quarry pits and the associated debris dominate the site space. Almost all distributions center on quarry pits, and there is a steady fall-off in the frequency of artifact classes away from them. Quarry pits are associated spatially with usable toolstone deposits. Several thousand years of opalite extraction have embedded quarry features in a carpet of debitage and opalite debris. Even when erosion or burial render pits and adits invisible on the surface, a distinctively large debris pile often characterizes bedrock extraction areas. These debitage "aprons" probably are a sort of "superfeature," composed of overlapping reduction feature/lithic scatters. As debitage analysis has shown, such superfeatures differ from reduction feature/lithic scatters and quarry pits in their technological genesis since they contain more early reduction and extraction debris than the former, and more later reduction debris than the latter.

Another sort of superfeature at Locality 36 is the quarry pit complex. Individual features on the surface of such complexes can be distinguished readily, but our investigations demonstrate clearly that quarry pits often were initiated on the berms of older features. Reduction feature/lithic scatters lie at the other end of a scale of feature complexity from such superfeatures. This feature type was recognized on the basis of discrete, definable, margins determined by a fall-off in debitage density. By definition, they can occur only away from quarry pit complexes and debitage aprons. Reduction feature/lithic scatters located near quarry pits simply may not yet be agglutinated into debitage aprons, while those farther from quarry pits may show a very different organization. The latter type manifest a high incidence of biface reduction, generally cover more area than features in the group nearer quarry pits, and may be associated with buried hearths suggesting that they are fairly young (perhaps ca. 500 years or less in age).

Feature distributions reflect how use of space was organized at Locality 36, but not what actions occurred in specific places or kinds of places. The distribution of debitage types and reduction attributes, stone tools, and stone tool attributes confirm that the focus of almost all activities was extraction of toolstone and production of bifaces; evidence for other activities from feature and artifact distributions is rare.

Tools used in the extraction of toolstone consisted primarily of hammerstones, made of opalite and of stone types exotic to the immediate vicinity. Opalite hammerstones were used expediently and discarded in quarry pits, as were other extraction tools, including bone and stone wedges; those of non-local material were more fragmented and often were recovered from reduction features (cf. Chapter 6). We assume that most debitage was discarded at the place it was created.

Debitage analysis suggests that, following toolstone extraction, initial processing occurred in one of four settings: within quarry features, on debitage aprons, at reduction/lithic scatters, and in non-feature settings. Initial processing or core reduction, therefore, is the most widespread of all lithic reduction activities, suggesting that it was organized least or had the fewest spatial constraints. The next stage of processing (blank preparation and early biface thinning) occurred most commonly in three settings: quarry pits, debitage aprons (or the group of reduction/lithic scatters nearest to quarry pits), and reduction/lithic scatters farthest from quarry pits. Debitage distribution suggests that prehistoric knappers were relatively indifferent as to the particular kind of feature setting in which they produced early stage bifaces, but clearly they preferred to work on these objects in feature settings. Late biface thinning, on the other hand, is associated with only two settings, occurring in reduction feature/lithic scatters and in non-feature areas.

The pattern of associations with feature contexts among bifaces differs from the patterns we have observed in debitage. On the whole, bifaces were discarded most often in quarry pits, and stage of biface reduction and attributes related to it have clear spatial patterns. Complete but un-heat-treated early stage bifaces made on block blanks were discarded most often in quarry pits. On the other hand, broken, late stage bifaces produced from flake blanks are more common in reduction feature/lithic scatters.

Assuming that bifaces also were discarded in the contexts where they broke or were found unsuitable, a scenario of biface production incorporating both debitage and biface distribution studies can be sketched. Remember that debitage suggests where reduction occurred and the biface assemblage suggests where reduction failed: Initial blank preparation and early biface thinning occurred in contexts which we recognize as archaeological features. Early stage reduction of block blanks failed most often in quarry pits, but flake blank discards are rare in this context. This dichotomy in the context of reduction for the two blank types makes economic sense when the place of final processing and heat-treatment is removed from place of extraction. Compared to flake blanks, blocks tend to weigh more, have greater waste-to-tool ratios, and higher failure rates. The marginal value model presented previously (Elston 1992b) suggests a considerable payoff in reduction of blocks at the point of extraction. When bifaces or biface blanks (often flake blanks) were removed from the quarry pit and quarry apron to more distant parts of the site (more than about 20 m from quarry pits), they were reduced further and heat-treated. Late stage production (Stage 4 and Stage 5) is rare at Locality 36, but when it did occur, it almost always was away from quarry pit areas.

Chronological Change at Locality 36

Stratigraphy and radiocarbon dates reveal some temporally and spatially variable patterns of toolstone exploitation at Locality 36.

The Type 2 setting, where beds of opalite toolstone embedded in softer tuff intersect a sloping surface, is common at Tosawihi Quarries, and offers a relatively low cost opportunity for prehistoric quarriers. At Locality 36, this opportunity was seized in Feature 102, in the least costly bedrock setting, about 4000 years ago. Thus, the first instance of bedrock quarrying presently known at the locality occurs in the middle of the No Name Phase (Elston and Budy 1990). If even earlier quarrying occurred at Locality 36, trenching failed to sample it and its evidence has been destroyed by subsequent quarrying. Earlier quarrying would have been most likely in Area B, which, although highly churned, returned the earliest radiocarbon date of 4090 B.P.

Even though exploitable toolstone remained in Feature 102, quarrying there ceased after a relatively short interval. Perhaps those early quarriers could pick and choose among other localities offering the same or better returns. In any case, Feature 102 was abandoned, and it filled with colluvium. This, and other examples of buried features with no surface expression, reminds us not to let all our attention be captured by the impressive surface archaeology of Tosawihi Quarries. The complex subsurface deposits are likely to contain many features unforeshadowed by the nature of the surface veneer.

It is possible that lack of radiocarbon dates between 3,700 B.P. and about 1400 B.P. at Locality 36 indicates a real hiatus in quarrying there. If true, however, it is counter to the steady increase in the intensity of quarrying at Tosawihi, culminating in the Late Prehistoric (Elston and Drews 1992). Radiocarbon dates from Locality 36 indicate an increase in quarrying intensity between 620 B.P and 220 B.P., during the latter part of the Eagle Rock Phase (Elston and Budy 1990), possibly extending into the early protohistoric. During this last interval of quarrying, all three quarry areas were utilized, and quarriers worked toolstone in Area A and portions of Area B where extraction appears most costly. If this is true, competition for toolstone at Tosawihi was so great by this time, that simply moving to a fresh, more productive quarry location was no longer an option.

Variation in the distribution of biface reduction through time suggests change in use of space at Locality 36. We proposed previously that as quarry use intensifies, and coarse debris accumulates, quarrying areas should become less suitable for certain activities, which should tend to be moved elsewhere. Feature 102 in Area C is the earliest quarry feature so far discovered at the locality, and the distribution of distinctive swirled opalite bifaces and debitage indicates that reduction most frequently occurred *within* the quarry pit. Thus, it seems there was little separation of processing by context when quarrying first began. In fact, Area C generally contains late bifaces and early debitage, suggesting that biface thinning occurred somewhat outside quarry pits, but close enough for failed bifaces to be discarded in pits. Both early stage bifaces and early stage debitage are associated with Area B, perhaps indicating that, later on, most later stage reduction occurred at some distance from quarry pits in contexts now comprising part of the debitage apron. Area A, the youngest of the three, contains high proportions of late stage bifaces and debitage. This suggests a return to late stage reduction in close proximity to quarry features, perhaps because Area A was not used long enough for accumulation of coarse debris to become a problem. Such accumulation also may have been retarded in Area A by the nature of the soft tuff bedrock and continued accumulation of loess. Area A appears to be associated with the latest use of Locality 36, when discrete reduction features and hearths were established on the ridge top nearby. This suggests that biface reduction required the space around the quarry pits in Area A and, sometimes, additional space nearby.

The Significance of Locality 36

Locality 36 has provided, for the first time at Tosawihi, an in-depth view into toolstone extraction and processing, two significant components of any lithic production system. Few other quarry studies have relied on such intensive subsurface excavation, which has been invaluable for examining extraction strategies. We now understand better how parent material inhibited or facilitated toolstone extraction, as well as how it influenced decisions to concentrate efforts in one part of the locality or another. We have confirmed the validity of our distance minimization transport model, gained better understanding of how the early stages of tool production were organized in space and time, and learned more of the relationship between specific processing techniques and blank morphology.

The ability of prehistoric people to modify the landscape (and archaeological deposits) through bedrock quarrying is well demonstrated at Locality 36. For example, the southern portion of Area B probably was a Type 2 setting originally, but it has been modified so extensively by quarrying that no evidence of its original morphology remains. That bedrock faces were sculpted into arcuate alcoves and pushed back many meters, while hundreds of square meters of bedrock surface were planed smooth, testifies eloquently to the effects of persistence over archaeological time, and to the extraordinary time and effort put into lithic procurement at Locality 36.

Locality 36 and Its Relationship to Other Tosawihi Research

The research design employed at Locality 36 grew out of our previous inquiries at Tosawihi. Conclusions of this earlier work are discussed in Chapter 1; here, we briefly consider whether findings derived from Locality 36 are consistent with earlier conclusions and how they may augment them.

A theme in all our earlier conclusions was that the prehistoric attraction of Tosawihi was toolstone, not food. We found nothing at Locality 36 to suggest otherwise. At Locality 36 and among almost all other Tosawihi sites we have studied, evidence for procurement and processing of any resource other than chipped stone is rare. Locality 36 is consistent with our earlier conclusion that quarries seldom were used as base camps, serving instead as peripheral/ ephemeral use areas in either the diurnal or logistical radius of base camps, save for the possibility that the large lithic scatters and a few hearths on the central ridge, dating later than 500 B.P., *may* reflect a change to short-lived residential occupations of the site.

The archaeology of Locality 36 is consistent with another theme of our earlier conclusions, that quarrying was relatively standardized in terms of the products removed from toolstone sources. Tool production at Locality 36 may have differed in detail, but on the whole was quite similar to that at other quarry localities we have examined; it suggests how Locality 36 fit in a settlement pattern and tool production sphere. First, we know that Locality 36 was exploited for its toolstone deposits and little else. Second, compared to other Tosawihi sites, the stone tools produced at Locality 36 are similar in kind (bifaces), shape, and size, and were transported off site at approximately the same point in the biface reduction sequence. Third, Locality 36 fits into regional settlement in terms of its role as a toolstone source, never serving, so far as we can tell, as a long term base camp or hub in its own right.

Prior to confronting Locality 36, we had had no opportunity to examine the "heart" of the Tosawihi quarries. Even so, the overall pattern of peripheral site composition and distribution relative to natural resources suggested that intensification of use occurred in the Late Prehistoric. Chronological change evident at Locality 36 confirms the larger pattern of Late Archaic intensification.

Perhaps it is not surprising that Locality 36 resembles sites within a two mile radius; in fact, our earlier study demonstrated that, even 12 km away, biface production, as opposed to use, remained primary. Yet, there is no denying that similarity of assemblages is strongly determined by proximity to toolstone such that the central quarries at Tosawihi (i.e., site 26Ek3032) have a strongly deterministic effect on the sites around them; with greater distance the effects of toolstone production on assemblage content, site arrangement, etc., diminish.

Significance of a Sample Survey in the Tosawihi Quarries Vicinity

After four seasons of testing and data recovery at more than 70 locales in and around the Tosawihi Quarries (26Ek3032), we learned a great deal about prehistoric economic behavior relative to the extraction and processing of lithic material (Elston and Raven 1992). Still, unanswered but important questions remained about the role of the quarries and their peripheries in a larger geographic and economic system. Did the outlying uplands function as part of an economic system that supported exploitation of the Tosawihi Quarries? Did use of the uplands, as a whole, focus explicitly on heretofore unknown toolstone sources, on 26Ek3032 sources, or did some other, non-lithic resources invite their occupation?

To answer such questions, we mounted a 10.3% random, stratified sample survey of about 28,000 acres surrounding the Tosawihi Quarries (Leach and Botkin 1992). The survey was intended to provide a larger context within which to view the quarries and to evaluate how quarrying fit into the larger prehistoric settlement/subsistence round.

We found that the attraction of the principal quarries dominated lithic exploitation throughout the survey region, and perhaps the territory beyond. Sixty-one mapped silicification zones within the study area were field-checked for toolstone quality and evidence of prehistoric use, and the nature and intensity of quarrying efforts were assessed. The largest silicification zones immediately adjacent the main quarries were used most intensively. They offered a broader selection of assayable material than did smaller, more scattered sources, and were convenient to the intensively-used quarrying and logistical support facilities of 26Ek3032. Opalite sources considerably beyond the main quarries went largely unexploited. Their generally poor quality seems only partly the cause; instead, distance from the "known" and well-tested deposits of 26Ek3032 appears to account for their lack of use. Thus, proximity to previously-explored sources and to support facilities appears to have conditioned use and reuse of adjacent sources.

Old quarry facilities (quarry pits) attracted repeated reuse. Scavenging usable toolstone in old quarry pit berms, using old hearths and other facilities, exploiting old exposures and the like, may have provided the most cost-effective methods of toolstone acquisition in some circumstances. Moreover, once established, it always was cheaper to return to the quarries for toolstone than to initiate new exploitation of previously untapped (and possibly unprofitable) sources beyond the periphery.

The *production sphere* of Tosawihi Quarries extends for a considerable distance beyond the quarries themselves (though the density of reduction features declines dramatically with distance). The evidence of biface and debitage discard within the survey region suggests that most lithic production originated at the quarries rather than at raw material sources well beyond them. The formed artifact assemblage of the survey study area is dominated by bifaces, and represents an extension of the same homogeneous production trajectory established at 26Ek3032. The survey assemblage contains higher proportions of late stage bifaces than do other Tosawihi study areas (e.g., the Eastern and Western Peripheries; cf. Bloomer, Ataman, and Ingbar 1992); the region is geographically and technologically farther along a production and distribution network that originates at the quarries. Spatial variability in the distribution of bifaces patterns predictably.

Large proportions of bifaces (particularly early stage bifaces) were discarded nearer the quarries, where they were produced and broken in manufacture. Later stage bifaces tended to be produced and discarded farther away. Yet, the occurrence of early stage bifaces and middle stage reduction debris out to the limits of the study area suggests that the survey region still fell well within the Tosawihi *"zone of production."*

To the limits of the survey area the archaeological record is dominated by lithic production: opalite tools were *produced* but *used* relatively little. Observed artifacts pertain overwhelmingly to the extraction and processing of opalite. At examined water sources, assemblages derive predominantly from opalite processing even when far from opalite supplies. Maintenance/ subsistence components of these locales, although occasionally abundant, appear to reflect tasks ancillary to toolstone processing (like comparable remains at similar sites studied in the heart of the quarries [cf. Leach 1992]).

Having discovered that the Tosawihi *zone of production* extends to and perhaps even beyond the limits of our survey region, we acknowledge that our understanding of the way Tosawihi products were transported over greater distances and how ultimately they were *used* falls far short of complete. The role of Tosawihi opalite in regional trade and exchange networks, and the function of Tosawihi products in daily subsistence and technological activities can be informed only by survey and excavation of sites farther afield.

Directions for Future Research

As with any large-scale research project, our work has generated as many questions as answers. Some of these can be addressed using different perspectives and techniques to examine the data and artifacts already collected; others require additional fieldwork.

The Tosawihi Quarries in a Larger Regional Context

Principal among the objectives of future Tosawihi research will be documentation of the role played by the quarries in the prehistoric adaptive strategies of the broader Upper Humboldt region. To date, our economic models and analyses have emphasized costs and returns of toolstone procurement. Work has focused almost exclusively on the quarries proper and the surrounding zone of toolstone production, and technological studies have emphasized aspects of toolstone extraction and processing. To understand the function of Tosawihi Quarries and the role of Tosawihi opalite from a regional perspective, the scope of inquiry must be expanded into the zone of toolstone use. It is here where the benefits of toolstone procurement accrue, where we expect to find evidence of the use of Tosawihi opalite in daily subsistence chores and technological activities, and where its role in regional trade and exchange networks should be expressed most clearly.

Examination of the influence of costs and benefits on technological organization in lithic terranes different from Tosawihi include studies of sites in the Carson Desert (Raven and Elston 1989) and of outcrop quarries and workshops in the Maverick Springs Range (Moore 1991a). In the region around Tosawihi Quarries, however, the economics of tool use and maintenance have been modeled only in the study of James Creek Shelter (Elston and Budy 1990). Further attention devoted to developing these models, and testing expectations derived from them against the archaeological record, will be enlightening. A first step would involve re-examination of extant archaeological collections from sites in north central Nevada at various distances from Tosawihi, but within the zone of Tosawihi toolstone use. These include the Valmy sites (Elston et al. 1981), Treaty Hill (Davis, Fowler, and Rusco 1976; Rusco and Jensen 1979), Rock Creek (Clay and Hemphill 1986), James Creek Shelter (Elston and Budy 1990), South Fork Shelter (Heizer, Baumhoff, and Clewlow 1968; Spencer et al. 1987), Rossi Mine Sites (Rusco et al. 1982), and the Carlin sites (Rusco, Davis, and Jensen 1979). Insights gained from such studies then could be applied to a more formal regional survey.

In order to examine the role of Tosawihi opalite as a commodity in trade networks, it will be necessary to sample sites along suspected transportation corridors between Tosawihi and the Humboldt Sink, western Utah, and the Snake River.

Questions Specific to Locality 36 and Tosawihi

Chronology

Among the many questions which invite further research, chronology figures prominently, in both long and short time frames. In the Great Basin, where surface sites dominate, organic preservation is often poor, and where many components of archaeological assemblages persist through long periods, dating almost always is difficult. This is compounded by the heavy disturbance produced by quarrying activity.

In previous work at Tosawihi, radiocarbon assays, time diagnostic projectile points, and obsidian hydration studies provided broad outlines of prehistoric activity, while extensive radiocarbon samples from Locality 36 have allowed tentative reconstruction of a sequence of utilization of that site. We observe three periods of exploitation at Tosawihi: 1) the Pre-archaic is represented widely but not extensively, and exploitation may have been confined to expedient use of opalite; quarrying or opalite collection may not have been the main object of visits to the area; 2) through most of the Archaic we see continuous use of the quarries and substantial extraction efforts; 3) in the Late Archaic there occurred an intensification of quarry use, whether produced by larger populations, more groups, or other impetus for increased demand.

Further inquiry into chronology could clarify this pattern and could address more specific questions about strategies of toolstone procurement and processing. Carbonate samples can be dated in order to provide gross measures to limit the age of overlying deposits and indicate later disturbance. In the case of quarry sites, carbonate dates could indicate reworking of previously abandoned deposits in the absence of charcoal or clear stratigraphic patterning.

The analysis of larger obsidian samples using hydration and sourcing techniques could provide a range of detailed data at sites where quantities of obsidian debitage occur. This does not apply to Locality 36, where only a few obsidian artifacts were recovered, but numerous assemblages from sites in the Eastern and Western Peripheries yielded large obsidian debitage samples. The relative intensity of occupation at various sites in various periods, the integrity of reduction features, the use of space at different periods, and differences in the organization of space through time could be investigated with such data.

Similarly, sourcing opalite will be useful. For example, tracing the source of opalite in dated reduction features can help delineate chronological patterns of intra-site use. Color, pattern, and texture differences appear to have some utility in source definition, but chemical analyses may be more precise. Under ultraviolet light, at least some varieties of Tosawihi opalite reflect light with a characteristic green glow. We compared samples of Tosawihi opalite to other Nevada cherts with promising results. Non-obsidian projectile points made of what appear to be raw materials exotic to Tosawihi reflect differently from Tosawihi material under ultraviolet light, but we are unable to discriminate among Tosawihi opalite sources. Similarly, a pilot study using neutron activation analysis successfully sorted Tosawihi chert from other white cherts (Elston 1992a), but whether different Tosawihi sources can be distinguished remains to be determined. Another untested, but potentially useful, fine-grained sourcing technique is proton-induced x-ray emission (PIXE; cf. Banks 1990).

Fine grained analysis of stratigraphic patterns may lead to better chronological control over quarrying strategy sequences and duration of utilization. Since only one large scale outcrop quarry (26Ek3208) and one quarry pit complex (Locality 36) have been investigated in detail (and they were quite different from one another), it would be informative to see if the same internal stratigraphic structures exist in other large sites. This could resolve whether the same strategies were used in similar geological circumstances or whether the differences are temporally dependent.

The excavation of rockshelters (several occur within the boundaries of 26EK3032) could contribute chronological data through better stratigraphic control and preservation of organic remains. In addition to greater potential for datable carbon samples, rockshelters often yield subsistence data and seasonal occupation indicators which are scarce at presently excavated Tosawihi sites. This in turn could help to refine the model of quarry use.

We are interested particularly in the earliest use of the quarries. What factors increased demand for toolstone and led people to undertake the difficult task of bedrock quarrying? Detailed studies of a number of Tosawihi Quarry localities are needed in order to understand the nature of the earliest quarrying. Locality 36 is a start, demonstrating that intensive quarrying took place there as early as 4000 years ago, but whether this site is typical of other quarries is unknown. The factors leading to first use of specific quarrying areas remains to be discovered.

Technological Issues

In a production setting, such as a quarry, technology is an important factor in determining strategies of production and processing. We have designed our analyses to evaluate variability in technology and in technological organization through time, but with only limited success. For the most part, we have noted an unchanging technology in biface production throughout the use of the quarries, although we have recognized some changes in use of space and labor organization through time (cf. Chapter 12). A more fine-grained approach could determine if this actually is the case or if more subtle changes are indicated.

Specialized reduction techniques were noted at Locality 36; although these do not pattern obviously through time, no analytical exercise has been applied to other Tosawihi assemblages. Other specialized techniques may remain to be observed, and we have yet to look at characteristics (such as flake scar patterning or incidence of particular failure types) which could vary through time and provide evidence for technological change. Perhaps the lack of technological change is characteristic only of the Tosawihi production sphere; further away, temporally different strategies of tool use and maintenance may be revealed.

We have looked briefly at how the artifact assemblages from Locality 36 compare to other Tosawihi quarry sites (cf. Chapters 4, 5, 6), but our artifact sample from other sites is limited. With data in hand we cannot make statistically reliable statements regarding the similarity of Locality 36 to other quarries. Larger samples would allow us to examine common or variable responses to particular extraction and processing problems, and would help resolve whether extraction and processing strategies are more nearly a function of geological setting or of other factors.

It also would be useful to examine the details of biface manufacture at sites to which unfinished Tosawihi bifaces were transported for final reduction and use. If later stages of reduction follow patterns observed at Tosawihi sites, a technology common to both producers and users of Tosawihi bifaces would be indicated. Differences might reflect craft-specialization among producers, differential access to the raw material source, or other differences.

Site Formation

As a result of our investigations at 26Ek3208 and especially at Locality 36, we understand a great deal more about site formation processes at quarries than previously; several specific problems remain unresolved, however, or demand more attention. Natural versus cultural deposition and sorting of quarry deposits still is problematic in that the natural rate of modification by geomorphic agents is unknown. To investigate this problem, a long term detailed sampling program could be initiated, perhaps undertaken over the course of a year, during which the deposition, infiltration, and mixing of cultural and natural materials due to runoff, wind, frost action, gravity, subsidence, and other factors would be monitored within experimentally produced debris deposits or selected prehistoric deposits located in the various geomorphic settings previously identified at quarry sites. Monitoring could include periodic sampling and analysis of materials caught in sediment traps or extracted directly from debris deposits. Close observation of the movement of large debris clasts, fine sediment, and individual artifacts over time would be important for understanding the potential for cultural and natural material accumulations in diverse geomorphic settings. In addition, as noted above, obsidian hydration and sourcing could be used to examine feature contexts and perhaps reveal whether discrete features are younger and dispersed features older once a clear understanding of the influences of slope, soil type, and other geomorphic factors are better documented.

In addition to site modifications due to natural processes, the stages of quarry pit formation are not well understood. Isolation of columns of pit deposits by the intersection of four or more trenches, recording of the multiple aspects revealed in the profiles, and detailed stratigraphic excavation based on three dimensional exposures could lead to a more secure reconstruction of pit formation processes. Finally, total excavation of quarry pit fill would reveal the ultimate shape and size of pits better than does trenching alone.

Spatial Analysis

In previous work, we observed a general pattern of artifact distribution whereby larger, less finished artifacts are more frequent near areas of extraction and artifacts become smaller and more finished with increasing distance from the quarry areas. This pattern is consistent with a benefit/cost model proposed subsequent to initial survey and testing and, as noted above, was supported by results from a survey of 28,000 acres in the hinterlands of the quarries. But on a finer scale, we have not observed if spatial patterns in the distributions and locations of functionally distinct artifact classes and activity areas *within* the quarry area support the patterns of distance minimization that we observed at its outskirts. While it may be unnecessary to excavate further to achieve this objective, more intensive survey along unbroken transects, detailed mapping, and in-situ technological analysis are indicated.

In the same vein, although we collected a good deal of functional data about sites peripheral to the quarries, we did not examine them on a feature-by-feature basis. By contrasting very specifically the activities which took place at the various sites and within different contexts at particular sites (with additional chronological input) we could view the relationships among activities, organization of space, labor, and technology. Much of the needed data are contained in our previous reports (especially Elston and Raven 1992), but some technological reevaluation and *additional feature excavation would* be needed.

Much of the discussion above relates to the uniqueness of Locality 36 in the Tosawihi context. At this point, we have some indications that Locality 36 is in some ways unlike other quarry sites such as 26Ek3208, 26Ek3084, Locality 26, and the outcrop quarries in Velvet Canyon (Elston, Raven, and Budy 1987). However, we cannot judge the extent of similarity or difference absent a similar level of investigation at several other quarry sites.

Methodological and Technical Issues

Intensive archaeological study of large bedrock quarries rarely has been undertaken (cf. Chapter 1). Quarries present an imposing challenge to archaeological research. Limitations on labor and funding for study of the volume of material presented by quarry sites, and the complexity of their archaeological records, require efficient, focussed, field and laboratory research. Consequently, we think it incumbent upon us to make a few brief comments about methods and techniques, particularly regarding the need for their further refinement.

Sampling

Sampling is a key component of research in quarries, since it is impossible to collect every artifact on such sites. The purpose of sampling is not to order the collection of objects; rather, sampling strategies order the collection of observations. Which observations are important is determined, of course, by the research design of any given inquiry. The salient point is that observations need not correspond directly to artifacts.

For example, the systematic random sample design of surface scrapes at Locality 36 (cf. Chapter 3) caused equal areas to be collected within each 10 m by 10 m block across the site. Counts and weights of flakes and angular debris (i.e., observations) made on the samples were extremely useful in defining site structure (cf. Chapter 10). Many samples, however, contained too few pieces of debitage to permit their characterization in debitage analysis. By the same token, samples from the debitage aprons and quarry pits contained many pieces of debitage. In fact, our original research design called for surface scrape samples to be used only as observations of count and weight; however, had we known in advance that we also would conduct more detailed analyses of the debitage, a different sampling strategy would have been selected. One of the drawbacks to areal sampling strategies is that when areas of high and low density are sampled at equal areal intensity, a size-diversity relationship is created (cf. Grayson 1984). In settings such as quarries, where densities of artifacts vary widely, sampling strategies must be tailored to the retrieval of observations, not solely of equal areas or even artifacts. A sampling strategy to overcome this problem would involve excavating contiguous units of known size until a minimum number (ca. 200-300) of items were collected. Thus, some parts of the site might take five or six surface scrape units to sample, others (such as debitage aprons) only one.

Stratigraphy and Excavation Strategies

Stratigraphy is always an important attribute of archaeological sites and this is nowhere more true than at quarry sites. Our work at Tosawihi disclosed extremely complicated anthropic stratigraphic sequences. Stratigraphic studies at quarries, including detailed profile drawings and descriptions of sediments, are necessary almost from the outset of research in order to allow an initial look at stratigraphy and determine appropriate sampling, recording, and dating strategies.

As work at Locality 36 has shown, one of the most important requirements of stratigraphic research at quarry sites is a thorough understanding of bedrock morphology in relation to younger natural sediments. While the Locality 36 research has been successful in this regard, more research on the relationship between different kinds of bedrock exposures and the resulting stratigraphic sequences would be extremely useful.

Part of the stratigraphic complexity owes to the overlaying of many quarrying episodes and their attendant debris. The tortuous stratigraphy created by human actions is complicated further by natural processes, as we have seen (cf. Chapters 7 and 8). Both archaeologists and geologists must study such complicated phenomena. For example, size variation in clast-supported stratigraphic units (cf. Chapter 8) could be the result of excavation within a single quarry pit (as exploitation strategies and actions changed with the development of the pit) or it could be caused by overlapping quarry rubble deposits from many different pits. Without some technique to separate rocks from different quarry pits (see discussion below on sourcing), the sole way to determine the genesis of a stratigraphic column is to remove each stratigraphic unit completely to derive a three dimensional profile of quarry complex stratigraphy.

Excavation strategies using mechanical trenching and other mechanized earth moving techniques, are integral to stratigraphic studies of quarries. Despite the loss of provenience on materials excavated by mechanical trenching, it is the most effective way to determine stratigraphic relationships and to guide other, more time consuming excavation techniques. The use of graders can be extremely fruitful. The utility of large scale scraping can be quite high, particularly in quarry sites, where features such as quarry pits and hearths can be detected easily. We recommend the use of mechanical excavation in general, then, as a mainstream excavation strategy in quarry settings. Obviously, we do not advocate the wholesale destruction of quarry sites by over-use of such equipment, nor should mechanized excavation supplant hand excavation or thorough surface recording.

Hand excavation within and outside quarry pits offers the most controlled method of site observation. Given its costs, and bearing in mind the provisos discussed above concerning sampling, hand excavations must be used in problem-solving fashion. For example, part of our research design at Locality 36 called for hand excavations in reduction feature/lithic scatters. We attempted to maximize the diversity of features sampled in hand excavations. For our purposes, this strategy worked quite well. However, we cannot use the data recovered to describe in detail the three dimensional occurrence of any particular reduction feature/lithic scatter. Data necessary for this sort of description would have required trading a few excavation units in many features for many units in one. Hand-excavation of entire features at Tosawihi is indicated.

Another issue for consideration at quarry sites concerns the most efficacious size of hand excavation units. Our basic excavation unit at Locality 36 was 50 cm x 50 cm x 10 cm. In some settings, these small units recovered more debitage than we could analyze and the samples had to be split (cf. Chapter 4). Other settings were extremely low in debitage density. The trend in archaeological research has been toward ever smaller excavation units, providing tighter spatial control. This is useful in some contexts, but as would be true if mechanized equipment were not used, one may miss the forest for the trees by using very small units as windows into much larger spatial phenomena. Quarry features and many of the associated lithic scatters are big, covering tens of square meters, and their spatial patterning usually is evident at large scales, not small ones. Thus, it is worth considering using larger excavation units to cover more area with little more effort.

Dating Techniques

The development of new dating techniques is always needed in archaeological research. Once established, quarries may be used for thousands of years, making dating essential to studies of toolstone acquisition through time. Because quarry sites tend to contain huge amounts of inorganic remains, there is a pressing need for better methods of dating such material. The abundance of inorganic artifacts and debris masks datable organic remains, further exacerbating the problem. Obsidian hydration dating is presently our sole technique for inorganic dating at Tosawihi, and it is best used as a relative technique rather than for absolute age determination. Extant techniques not used at Locality 36, yet perhaps useful at other quarry sites, include thermoluminescence and archaeomagnetic dating. Although these two techniques have stringent requirements concerning sample context, the necessary conditions for using them may be present in other quarry localities, particularly those in which heat-treatment of raw material was common. Since silicious stone in a quarry may be relatively uniform in chemical composition and samples selected can be from similar depositional contexts, measuring patination rinds on artifacts (Purdy 1981) might provide a useful *local* relative dating technique.

Remote Sensing and Mapping

Remote sensing could be an extremely important tool in quarry research. The ability to detect surface and subsurface variation in archaeological and geological deposits could be very cost effective and could help focus inquiry. One potential use of remote sensing is to determine bedrock morphology, perhaps with ground penetrating radar. As shown at Locality 36 (cf. Chapters 9 and 12), thorough knowledge of bedrock morphology assists stratigraphic and anthropological interpretation immensely. Other remote sensing technologies, such as multi-spectral scanning, infrared photography, etc., could be useful in mapping quarries if the albedo of waste rock is distinctive from background reflection.

Mapping quarry sites is rarely undertaken, probably because of their size. We were fortunate at Locality 36 to have an excellent photogrammetric map in hand prior to initiating fieldwork. Although this map was prepared at 1 m contour intervals, we could have obtained even finer contour intervals, perhaps allowing us to discern individual quarry pits. Whether through photogrammetry or terrestrial survey, detailed maps of quarry localities substantially aid field planning. In any case, one topic for future consideration is the accuracy with which quarry features can be discerned on photogrammetric maps relative to maps made by terrestrial survey. And, the efficacy of combining aerial photogrammetry or terrestrial survey with remote sensing data to generate accurate portrayals of quarry sites should be explored.

Phased Fieldwork

Many of the comments made above suggest that a particular field method be used to guide further field inquiry. A logical extension of this is the notion that quarry investigations should, ideally, proceed in phases. Each phase can inform the next, given sufficient time to process results of the earlier work. In this fashion, the available resources for a research project can be used most effectively. Practical considerations may impede undertaking phased field research, but it is a goal worthy of seeking.

Material Sourcing

Sourcing lithic raw material is an inviting prospect. Above, we mentioned how sourcing opalite to particular quarry locations in the Tosawihi area could be useful, and the same benefits could accrue to any quarry study. Presently, obsidian sourcing is the most developed lithic sourcing technique available. Chert sourcing through chemical characterization (e.g., neutron activation, x-ray fluorescence) or qualitative attributes (color, texture, fluorescence under ultraviolet light) is in its infancy. In quarry sites, the need is particularly pressing for a sourcing technique that is fast, inexpensive, and can be applied to many artifacts. Ultraviolet fluorescence may provide a useful technique for many materials (Hofman, Todd, and Collins 1991), including Tosawihi opalite (Elston 1992a).

Tool and Debitage Analysis

In the research presented here and in other reports on Tosawihi research (Elston and Raven 1992), we have outlined our analytical techniques explicitly so that others can use, criticize, or discard them.

Earlier (cf. Chapter 4), we contrasted three debitage analysis techniques for these same reasons, concluding that, while mass analysis is fast and repeatable, it is less accurate and thus has less utility than other techniques. One suggestion for future research in quarry settings is to *continue* using a variety of analytical techniques on the same debitage assemblage. It then may be possible to determine why some techniques work in one setting but not in another. Mass analysis may be suitable in some regions or at some site types, while unsuitable at others. Also analyses of controlled experimental reduction sequences could be continued, but in a "realistic" fashion by mixing many sequences to simulate the undoubtedly common mixtures of debitage found in quarries (and many other sites too). Continued experimental flintknapping is a third direction for future research. A fourth, overarching methodological need is for a technique of debitage analysis that yields information at the same level of generality as our hypotheses. To examine variation in the transport and reduction of toolstone in the Tosawihi vicinity, or at any other quarry, we must develop a reliable assessment of core or biface reduction stage *and* size simultaneously.

Analysis of stone tools from Locality 36 indicates a need for continued research on the causes of failure in stone tool manufacture and how (or if) they are evident on broken pieces. More replications using various flintknappers, tools, and raw materials will help refine the breakage typology.

Another question involves how best to detect specialist flintknappers in the archaeological record of quarry localities and other sites. Once again, we believe the answer lies partly in continued experimentation. Close contrasts of tools and debitage from discrete archaeological features might contribute usefully.

Site Structure Studies

The distributional studies presented here (cf. Chapter 10) are merely an initial step toward understanding site structure. Our distributional analyses suggest that size profiles of debris channel certain activities to occur elsewhere. Can this be shown at other sites (regardless of where they are)? The question remains open. As well, there is great need for a body of theory concerning site structure (Binford 1983), since at the moment it remains a largely speculative enterprise in which the archaeologist attempts to find individual behavioral events. This is not much more than story-telling, particularly in complicated trash deposits like those of quarry sites. Lastly, how typical is Locality 36 of bedrock quarry sites in general? Is there a consistent pattern of debitage aprons, quarry pits, and distinct reduction features? There is much ground for comparative research on such questions.

Experimental Studies and Actualistic Research

Experimental and actualistic studies of lithic reduction, quarrying, and toolstone extraction have played an important role in the Tosawihi research. Our experimental studies are not yet conclusive, and perhaps none ever can be, since there are many variables affecting any human action. Nonetheless, there is definite need for more such studies in the future.

Experimental flintknapping should be one part of an integrated program of experimentation. Making the entire quarrying, extraction, and processing sequence a single experimental program would permit measurement of the energy or time needed to make a stone tool. As our discussion of the economics of extraction and processing at Locality 36 showed, benefit-cost ratios may vary depending upon how toolstone occurs. Expansion of this kind of integrated experimental program within Tosawihi quarries holds promise for the future.

On the other end of the spectrum from experimental quarrying, extraction, and processing lies experimental tool use. We have done experimental butchery, woodworking, and other tasks with Tosawihi opalite replications, but have not formalized these into an experimental program. Perhaps by comparing the functional properties of Tosawihi opalite with those of other regionally available lithic raw materials we could determine if Tosawihi opalite was a superior material and hence attractive to hunter-gatherers. As well, we do not understand the use histories of Tosawihi bifaces outside their production sphere; experimental tool use in tandem with regional archaeological research could inform about the entire cycle of use, maintenance, and discard of Tosawihi opalite.

Potential for Continued Problem-Oriented Analyses Using Curated Tosawihi Collections

Our four-year program of archaeological survey, testing, and data recovery at Tosawihi has resulted in collection of more than a million artifacts, artifact lots, and cultural and noncultural samples (rock and soil specimens, radiocarbon and flotation samples, and the like). The Tosawihi collection, curated by the Nevada State Museum, Carson City, Nevada, probably represents the largest fully-documented archaeological assemblage in the state and one of the best documented quarry collections in the world. Results of in-depth artifact analyses and data from site and feature inventories reside in a flexible, translatable database management system.

Thus, there has been amassed a superb collection, with attendant databases, that can provide almost unlimited research opportunities to other investigators. We have spent some pages in this chapter developing issues for future research, and many of them are accessible with the data in hand. Using the collections and mapped data, researchers can explore in far greater detail than we have the relationships between activities in space and time.

Many reduction features were collected in their entirety, providing opportunities for in-depth technological and spatial analyses, as well as other kinds of question-driven debitage and tool studies. For example, sampled reduction features at Locality 36 could be compared with other Tosawihi features, wholly-excavated during testing and data recovery at peripheral sites, to address the spatial and technological variability manifest between quarrying locales and other, functionally-discrete locations. As raw material-sourcing techniques are refined, questions about intra-quarry material transport can be pursued. Finally, the magnitude of our collections provides an opportunity to examine methodological issues relating to sampling and collection technique.

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Appendix A

Debitage

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
2599.0	0	0	0.00	0.00	QEI	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	Q*M e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QM*BEI	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QMBE*L	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QM*B*E	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QM e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QM e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	QM E	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	Q*	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	Q* BE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	72	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	111	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	111	0	0.00	0.00	M*B*EI	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	111	0	0.00	0.00	MB*E*I	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	111	0	0.00	0.00	Mb	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	QM E	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*MBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*MB	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*MBe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M E	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*M e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*MBe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	102	0	0.00	0.00	Q*Mb	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MB	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QMBE*L	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q* EI	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QM e	unanalyzed	unanalyzed	opalite	n/a																			

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
2599.0	71	0	0.00	0.00	Q*MBel	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MEl	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*ME	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QM*BEl	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*M e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QmB*E*l	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MbE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q* E	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*M e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*Me	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q* e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*ME	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	QMBEl	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*MBEl	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	71	0	0.00	0.00	Q*Mbe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*MBe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*MBe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*Mb	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*MBe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*M*be	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	QM*BE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	22	0	0.00	0.00	Q*M E	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	22	0	0.00	0.00	QMBEL	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	22	0	0.00	0.00	QMBe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	22	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	27	0	0.00	0.00	Q*ME	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	32	0	0.00	0.00	Q*Me	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	QMb	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*MBe	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*M e	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*M E	unanalyzed	unanalyzed	opalite	n/a																			

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
2599.0	42	0	0.00	0.00	Q*M E	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*MBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	qmB*E*	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*M	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*Mb	unanalyzed	unanalyzed	opalite	n/a																			
2599.0	42	0	0.00	0.00	Q*MBE	unanalyzed	unanalyzed	opalite	n/a																			
4002.1	0	0	103.39	68.19	unanalyzed	Mass Reduction	Q	opalite	1.00	665.6	4	826.8	3	86.4	5	87.2	4	107.1	20	90.5	18	11.4	17	5.2	6	5	618.60	721.7
4006.1	42	6	102.57	64.28	qM*B*e	Mass Reduction	MBe	opalite	1.00	174.5	1	728.5	5	613.1	24	493.4	20	194.3	38	325.0	60	118.9	198	59.4	88	4	716.80	1269.0
4007.1	42	7	102.36	63.30	QM*b	Mass Reduction	MBe	opalite	1.00	111.7	1	356.2	2	161.3	8	379.5	12	152.1	41	114.9	25	70.0	110	22.2	34	4	412.00	744.5
4009.1	42	0	101.95	61.34	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	552.4	3	33.8	1	100.4	4	41.1	5	16.9	3	2.6	5	0.9	2	2	1131.70	1227.7
4010.1	42	10	101.74	60.36	Q*M*be	Mass Reduction	MB	opalite	1.00	0.0	0	831.5	6	303.9	7	527.4	12	119.1	23	296.6	31	43.9	73	27.5	35	6	452.70	1115.9
4010.3	42	0	101.74	60.36	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.7	1	0	0.00	0.0
4012.1	0	0	101.33	58.40	unanalyzed	Mass Reduction	MBe	opalite	1.00	0.0	0	0.0	0	118.6	4	190.3	6	56.1	14	30.4	8	26.7	46	6.6	9	0	0.00	67.4
4076.1	72	0	72.28	108.22	unanalyzed	Early thinning	MBe	opalite	1.00	69.3	1	127.7	1	79.9	3	147.6	5	51.4	10	50.0	9	31.9	51	5.3	7	1	140.00	318.0
4077.1	72	77	72.95	107.48	m E	Early thinning	EI	opalite	1.00	0.0	0	0.0	0	20.5	1	87.0	2	48.7	13	43.8	14	36.8	93	21.8	34	0	0.00	129.0
4079.1	72	79	74.29	106.00	M*bE	Early thinning	BE	opalite	1.00	0.0	0	0.0	0	314.9	16	255.9	13	334.8	64	193.8	45	132.3	251	42.2	69	2	59.40	587.2
4082.1	73	82	76.30	103.78	qM*BE	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	13.8	1	260.7	12	111.5	25	131.7	25	70.7	156	32.8	43	3	186.50	449.2
4083.1	73	83	76.97	103.04	qMbE*	Mass Reduction	BE	opalite	1.00	0.0	0	0.0	0	160.4	6	204.2	9	105.0	35	105.0	24	77.0	147	22.5	46	2	130.80	502.2
4083.3	73	0	76.97	103.04	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.9	1	0	0.00	0.0
4087.1	71	87	79.65	100.08	mB*e	Mass Reduction	MBE	opalite	1.00	0.0	0	0.0	0	65.3	3	143.5	5	98.8	28	83.6	21	43.5	83	23.4	36	0	0.00	156.4
4088.1	71	88	80.32	99.34	mBE*	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	33.9	2	178.0	8	103.0	36	62.4	17	65.2	130	25.0	50	0	0.00	212.0
4091.1	71	91	0.00	0.00	M*be	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	22.4	2	137.5	6	52.5	15	91.3	20	32.7	66	20.7	33	0	0.00	174.6
4092.1	0	0	83.00	96.38	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	58.2	1	35.1	1	15.8	5	0.0	0	5.4	11	1.6	2	3	294.50	429.2
4096.1	72	96	0.00	0.00	M*Be	Edging	MBe	opalite	1.00	0.0	0	335.3	5	95.9	2	96.7	5	65.6	17	35.8	13	38.1	83	13.4	25	0	0.00	37.7
4097.1	72	0	76.14	108.40	unanalyzed	Mass Reduction	MB	opalite	1.00	360.4	1	144.2	1	52.5	3	257.4	6	34.5	9	56.0	11	16.7	44	6.3	19	0	0.00	74.6
4097.2	72	0	76.14	108.40	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.3	1	0.6	1	0	0.00	0.0
4099.1	72	99	74.78	106.94	QMBE	Early thinning	BE	opalite	1.00	0.0	0	152.7	2	41.4	5	119.0	5	55.4	19	91.5	25	39.3	111	31.6	66	4	346.10	634.6
4102.1	72	102	72.74	104.75	MBE	Mass Reduction	BE	opalite	1.00	0.0	0	0.0	0	157.3	5	51.7	4	110.6	25	63.2	16	39.6	86	15.3	31	1	39.10	250.9
4107.1	0	0	67.14	64.14	unanalyzed	Early thinning	BE	opalite	1.00	0.0	0	212.4	3	114.9	5	587.8	26	154.9	48	332.2	70	108.8	238	75.8	118	1	45.80	911.1
4107.2	0	0	67.14	64.14	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.7	1	0.0	0	0	0.00	0.0
4110.1	49	0	66.70	61.18	unanalyzed	Early thinning	BE	opalite	1.00	0.0	0	97.3	1	216.5	6	100.1	3	145.3	20	101.9	15	64.9	74	19.9	31	0	0.00	638.3
4113.1	49	0	66.26	58.21	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	557.5	1	236.9	6	205.9	5	47.6	4	111.0	7	3.9	6	0.3	2	8	2547.80	409.1
4115.1	49	0	65.96	56.23	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	1709.6	5	88.8	1	100.4	2	0.0	0	0.0	0	0.0	0	0.0	0	4	3345.80	3577.1
4117.1	49	0	65.67	54.25	unanalyzed	Mass Reduction	BE	opalite	1.00	0.0	0	0.0	0	184.2	7	224.7	5	124.2	29	105.9	19	78.2	126	15.7	32	0	0.00	673.1
4118.1	49	0	65.52	53.26	unanalyzed	Edging	qMB	opalite	1.00	332.4	2	320.8	2	6.5	1	74.0	4	55.0	8	34.5	8	15.4	21	13.8	20	1	322.10	814.9

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
4119.1	0	0	65.38	52.28	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	233.9	1	54.9	2	195.2	4	15.6	3	1.2	2	2.6	2	0.0	0	2	649.10	1347.5
4120.1	0	0	65.23	51.29	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	554.2	7	37.5	1	66.0	1	0.0	0	0.0	0	0.0	0	0.0	0	15	3800.00	4000.0
4121.1	0	0	65.08	50.30	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	230.0	2	0.0	0	170.0	2	0.0	0	0.0	0	0.0	0	0.0	0	13	3112.00	3259.0
4123.1	0	0	64.79	48.32	unanalyzed	Mass Reduction	MB?	opalite	1.00	0.0	0	0.0	0	32.8	3	62.6	4	100.3	24	155.8	23	20.0	43	10.4	23	5	3200.00	3056.0
4581.1	87	501	94.70	126.09	MBe	unanalyzed	unanalyzed	opalite	n/a																			
4582.1	38	502	101.97	113.46	mBE	Mass Reduction	qMB	opalite	1.00	0.0	0	0.0	0	18.3	2	422.1	22	40.4	19	39.4	11	9.9	23	7.4	10	0	0.00	53.0
4584.1	92	504	80.06	140.62	M*BE	Mass Reduction	qMB	opalite	1.00	209.2	1	392.9	6	78.6	6	373.8	14	114.8	21	75.1	15	19.9	36	8.0	15	0	0.00	77.0
4585.1	92	505	78.56	140.12	mBE*	unanalyzed	unanalyzed	opalite	n/a																			
4586.1	92	506	81.56	141.12	too small	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.3	1	0.6	3	0.2	2	0	0.00	1.1
4587.1	63	507	139.28	78.35	BEL*	unanalyzed	unanalyzed	opalite	n/a																			
4587.1	63	507	139.28	78.35	mB L	unanalyzed	unanalyzed	opalite	n/a																			
4588.1	63	508	138.48	78.95	EL	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	24.4	2	21.9	5	3.3	2	4.5	15	3.7	11	0	0.00	19.6
4588.1	63	508	138.48	78.95	ME	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	24.4	2	21.9	5	3.3	2	4.5	15	3.7	11	0	0.00	19.6
4588.1	63	508	138.48	78.95	ME	N TOO SMALL	too small	opalite	1.00																			
4589.1	63	509	137.28	76.11	B*	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	13.9	1	5.3	2	12.0	4	2.3	5	3.0	6	0	0.00	46.9
4590.1	6	510	162.27	29.99	mBE	Mass Reduction	mBE	opalite	1.00	0.0	0	210.7	2	76.8	9	358.2	17	48.1	22	111.2	24	33.9	95	37.3	63	0	0.00	44.5
4591.1	6	511	161.77	29.49	qMBe	Mass Reduction	qMBE	opalite	1.00	0.0	0	469.7	5	230.5	16	944.9	36	134.3	61	246.0	61	38.4	94	51.2	95	1	121.10	236.2
4592.1	6	512	161.27	30.49	mBE	unanalyzed	unanalyzed	opalite	n/a																			
4593.1	6	513	160.77	28.99	BEI	unanalyzed	unanalyzed	opalite	n/a																			
4594.1	6	514	162.27	31.99	BE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	4.4	3	8.3	2	3.9	10	2.7	8	0	0.00	10.1
4595.1	6	515	163.27	29.49	MBE	Mass Reduction	MBe	opalite	1.00	0.0	0	0.0	0	0.0	0	215.0	3	34.8	13	39.8	8	14.1	28	5.1	14	0	0.00	71.4
4596.1	6	0	161.77	27.49	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	19.7	2	3.1	2	5.5	2	5.2	12	6.2	14	0	0.00	0.6
4597.1	6	517	163.27	29.99	EI	unanalyzed	unanalyzed	opalite	n/a																			
4598.1	6	518	159.77	28.99	BE	unanalyzed	unanalyzed	opalite	n/a																			
4599.1	6	519	159.77	31.99	Mbe	unanalyzed	unanalyzed	opalite	n/a																			
4600.1	87	520	92.70	128.09	B	unanalyzed	unanalyzed	opalite	n/a																			
4601.1	87	521	93.70	127.09	MB*e	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	12.5	1	99.1	4	8.4	3	24.9	6	9.7	18	5.1	11	0	0.00	12.3
4602.1	87	522	95.70	127.59	B	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	35.6	4	5.0	11	2.0	10	0	0.00	29.9
4603.1	87	523	96.20	126.59	too small	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	1.4	1	0.0	0	1.1	3	1.5	5	0	0.00	0.0
4604.1	87	524	94.20	125.59	too small	unanalyzed	unanalyzed	opalite	n/a																			
4605.1	87	525	92.70	124.09	too small	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	3.5	1	2.6	6	0.7	2	0	0.00	0.0
4606.1	92	526	79.86	141.07	MBe	unanalyzed	unanalyzed	opalite	n/a																			
4607.1	92	527	80.86	142.07	BE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	10.6	3	0.0	0	3.3	5	1.5	5	0	0.00	1.1
4608.1	92	528	79.86	143.07	b	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	6.4	1	2.4	5	2.3	4	0	0.00	2.0
4608.2	92	0	79.86	143.07	unanalyzed	N TOO SMALL	too small	jasper	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.6	1	0.0	0	0	0.00	0.0
4609.1	92	529	78.36	142.07	MB*E	unanalyzed	unanalyzed	opalite	n/a																			
4610.1	92	530	77.86	141.07	BEI	unanalyzed	unanalyzed	opalite	n/a																			
4611.1	92	531	77.36	138.57	mB*E	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	67.6	4	0.0	0	4.8	3	9.1	3	4.8	16	4.8	8	1	14.70	18.4
4612.1	92	532	81.36	140.07	BE	unanalyzed	unanalyzed	opalite	n/a																			

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
4613.1	63	533	141.30	78.57	L	N TOO SMALL	too small	opalite	n/a																			
4613.1	63	533	141.30	78.57	B	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	16.3	4	26.9	6	5.3	15	0.0	0	0	0.00	22.6
4613.1	63	533	141.30	78.57	L	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	16.3	4	26.9	6	5.3	15	0.0	0	0	0.00	22.6
4614.1	63	534	140.80	76.57	bEL	Early thinning	BE	opalite	n/a																			
4614.1	63	534	140.80	76.57	BE	Early thinning	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	17.8	5	39.6	9	13.4	28	10.7	22	0	0.00	34.9
4614.1	63	534	140.80	76.57	bEL	Early thinning	BE	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	17.8	5	39.6	9	13.4	28	10.7	22	0	0.00	34.9
4615.1	63	535	140.30	77.07	BEI	Early thinning	too small	opalite	n/a																			
4615.1	63	535	140.30	77.07	BE	Early thinning	too small	opalite	1.00	0.0	0	96.9	1	16.7	1	63.7	2	40.5	10	39.4	10	12.6	36	6.9	18	0	0.00	20.0
4615.1	63	535	140.30	77.07	BEI	Early thinning	too small	opalite	1.00	0.0	0	96.9	1	16.7	1	63.7	2	40.5	10	39.4	10	12.6	36	6.9	18	0	0.00	20.0
4616.1	63	536	139.80	80.57	BEL	unanalyzed	unanalyzed	opalite	n/a																			
4616.1	63	536	139.80	80.57	mBEL	unanalyzed	unanalyzed	opalite	n/a																			
4617.1	63	537	137.80	80.07	E	unanalyzed	unanalyzed	opalite	n/a																			
4618.1	63	538	137.30	78.57	Mb	unanalyzed	unanalyzed	opalite	n/a																			
4618.1	63	538	137.30	78.57	BE	unanalyzed	unanalyzed	opalite	n/a																			
4619.1	63	539	0.00	0.00	mBE	unanalyzed	unanalyzed	opalite	n/a																			
4620.1	38	540	101.72	110.21	too small	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	2.3	1	0.5	2	1.7	4	0	0.00	0.8
4621.1	38	541	102.22	115.71	BE	unanalyzed	unanalyzed	opalite	n/a																			
4622.1	38	542	102.22	115.71	b	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	9.2	2	2.6	1	2.3	9	1.2	3	0	0.00	0.0
4623.1	38	543	103.72	113.71	too small	unanalyzed	unanalyzed	opalite	n/a																			
4624.1	86	544	81.60	121.18	MB*E	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	99.7	1	22.1	5	22.9	5	6.0	11	1.0	5	0	0.00	0.0
4625.1	86	545	81.10	123.18	B*E	unanalyzed	unanalyzed	opalite	n/a																			
4626.1	86	546	79.60	121.18	BE	Edging	BE?	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	33.4	7	17.4	7	17.2	47	9.5	29	0	0.00	13.2
4626.2	86	0	79.60	121.18	unanalyzed	N TOO SMALL	too small	jasper	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.4	1	0	0.00	0.0
4627.1	86	547	80.10	123.18	MBE	Mass Reduction	BE	opalite	1.00	0.0	0	0.0	0	85.7	5	285.7	14	81.0	16	113.3	23	43.2	103	25.1	51	0	0.00	6.4
4628.1	86	548	79.10	123.68	MBE	Mass Reduction	mBE	opalite	1.00	0.0	0	0.0	0	0.0	0	311.1	8	41.4	9	110.9	27	19.4	44	18.2	36	2	143.40	370.1
4629.1	86	549	79.10	125.18	BE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	1.3	1	8.1	2	3.2	9	3.6	8	0	0.00	8.1
4630.1	86	550	78.10	124.68	MBE	unanalyzed	unanalyzed	opalite	n/a																			
4631.1	86	551	77.60	124.68	mBE	Mass Reduction	mBE	opalite	1.00	0.0	0	0.0	0	26.1	1	87.0	5	38.8	13	88.4	24	15.4	38	17.5	40	0	0.00	178.4
4632.1	86	552	77.60	121.68	BE	unanalyzed	unanalyzed	opalite	n/a																			
4633.1	86	553	77.10	121.18	MBE	unanalyzed	unanalyzed	opalite	n/a																			
4634.1	86	554	78.10	125.18	qMB*E	unanalyzed	unanalyzed	opalite	n/a																			
4635.1	86	555	77.60	125.18	BE*	unanalyzed	unanalyzed	opalite	n/a																			
4636.1	63	536	137.30	80.07	BE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	8.9	2	0.0	0	6.5	9	0.4	3	0	0.00	9.5
4637.1	63	537	137.30	78.07	B*EL	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	32.8	1	0.0	0	21.1	5	45.5	14	13.6	33	9.0	22	0	0.00	9.6
4637.1	63	537	137.30	78.07	B*EL	Early thinning	BEI	opalite	n/a																			
4637.1	63	537	137.30	78.07	B*E	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	32.8	1	0.0	0	21.1	5	45.5	14	13.6	33	9.0	22	0	0.00	9.6
4638.1	63	538	0.00	0.00	mBE	unanalyzed	unanalyzed	opalite	n/a																			
5002.1	0	0	103.39	68.19	QM E	unanalyzed	unanalyzed	opalite	n/a																			
5005.1	0	0	102.77	65.26	QMB	unanalyzed	unanalyzed	opalite	n/a																			

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	G0 Flake fragments n	G0 Flakes w/ platforms wt.(g)	G0 Flakes w/ platforms n	G1 Flake fragments wt.(g)	G1 Flake fragments n	G1 Flakes w/ platforms wt.(g)	G1 Flakes w/ platforms n	G2 Flake fragments wt.(g)	G2 Flake fragments n	G2 Flakes w/ platforms wt.(g)	G2 Flakes w/ platforms n	G3 Flake fragments wt.(g)	G3 Flake fragments n	G3 Flakes w/ platforms wt.(g)	G3 Flakes w/ platforms n	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt. (g)
5006.1	0	0	138.00	26.00	QMB L	unanalyzed	unanalyzed	opalite	n/a																			
5007.1	0	0	102.36	63.30	QM	unanalyzed	unanalyzed	opalite	n/a																			
5009.1	0	0	101.95	61.34	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5011.1	0	0	155.00	31.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5020.1	0	0	138.00	19.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5021.1	0	0	147.00	10.00	QMBEL	unanalyzed	unanalyzed	opalite	n/a																			
5023.1	0	0	142.00	9.00	QMB L	unanalyzed	unanalyzed	opalite	n/a																			
5024.1	0	0	146.00	2.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5034.1	0	0	111.00	26.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5038.1	0	0	122.00	39.00	QMBEL	unanalyzed	unanalyzed	opalite	n/a																			
5045.1	0	0	155.00	49.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5051.1	0	0	143.00	56.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5059.1	0	0	120.00	49.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5060.1	0	0	120.00	43.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5067.1	0	0	104.00	66.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5072.1	0	0	99.00	65.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5073.1	0	0	88.00	50.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5077.1	0	0	85.00	70.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5078.1	0	0	83.00	72.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5085.1	0	0	107.00	82.00	QM L	unanalyzed	unanalyzed	opalite	n/a																			
5099.1	0	0	92.00	105.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5107.1	0	0	81.00	127.00	M E	unanalyzed	unanalyzed	opalite	n/a																			
5113.1	0	0	73.00	101.00	QM E	unanalyzed	unanalyzed	opalite	n/a																			
5114.1	0	0	72.00	109.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5120.1	0	0	62.00	99.00	MBE	unanalyzed	unanalyzed	opalite	n/a																			
5135.1	0	0	44.00	92.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5136.1	0	0	40.00	99.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5155.1	0	0	78.00	69.00	QM EL	unanalyzed	unanalyzed	opalite	n/a																			
5157.1	0	0	79.00	70.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5163.1	0	0	68.00	73.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5176.1	0	0	38.00	53.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5177.1	0	0	39.00	63.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5178.1	0	0	36.00	64.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5180.1	0	0	22.00	62.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5181.1	0	0	29.00	70.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5183.1	0	0	37.00	75.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5200.1	0	0	46.00	119.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5202.1	0	0	102.00	107.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5205.1	0	0	90.00	111.00	QM	unanalyzed	unanalyzed	opalite	n/a																			

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Fea-ture	Unit	N	E	Tech-nological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample frac-tion	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
5208.1	0	0	104.00	116.00	M	unanalyzed	unanalyzed	opalite	n/a																			
5209.1	0	0	108.00	125.00	M	unanalyzed	unanalyzed	opalite	n/a																			
5211.1	0	0	97.00	121.00	MB	unanalyzed	unanalyzed	opalite	n/a																			
5238.1	0	0	137.00	88.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5310.1	0	0	71.00	12.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5311.1	0	0	85.00	14.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5312.1	0	0	87.00	15.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5317.1	0	0	101.00	14.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5330.1	0	0	79.00	23.00	QMBE	unanalyzed	unanalyzed	opalite	n/a																			
5343.1	0	0	100.00	36.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5352.1	0	0	109.00	48.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5367.1	0	0	33.00	43.00	QMB	unanalyzed	unanalyzed	opalite	n/a																			
5370.1	0	0	43.00	39.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5375.1	0	0	56.00	46.00	QM E	unanalyzed	unanalyzed	opalite	n/a																			
5405.1	0	0	144.00	140.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5416.1	0	0	111.00	148.00	M	unanalyzed	unanalyzed	opalite	n/a																			
5425.1	0	0	88.00	138.00	B	unanalyzed	unanalyzed	opalite	n/a																			
5426.1	0	0	82.00	132.00	M	unanalyzed	unanalyzed	opalite	n/a																			
5433.1	0	0	61.00	131.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5434.1	0	0	61.00	138.00	M	unanalyzed	unanalyzed	opalite	n/a																			
5475.1	0	0	95.00	160.00	MB	unanalyzed	unanalyzed	opalite	n/a																			
5484.1	0	0	112.00	173.00	M	unanalyzed	unanalyzed	opalite	n/a																			
5489.1	0	0	87.00	178.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
5520.1	0	0	154.00	158.00	QM	unanalyzed	unanalyzed	opalite	n/a																			
6041.1	38	502	101.97	113.46	mBE	Mass Reduction	MBe	opalite	1.00	0.0	0	0.0	0	107.1	2	144.9	5	50.2	13	58.9	12	14.0	24	7.9	15	0	0.00	11.7
6081.1	92	504	80.06	140.62	MBe	Mass Reduction	QMb	opalite	1.00	127.3	1	1324.1	8	108.0	5	640.7	18	89.4	21	165.9	29	14.8	15	10.8	17	1	31.30	352.2
6081.1	92	504	80.06	140.62	M*bE	Mass Reduction	QMb	opalite	1.00	127.3	1	1324.1	8	108.0	5	640.7	18	89.4	21	165.9	29	14.8	15	10.8	17	1	31.30	352.2
6081.1	92	504	80.06	140.62	M*bE	Mass Reduction	QMb	opalite	1.00																			
6101.1	92	505	78.56	140.12	M*Be	unanalyzed	unanalyzed	opalite	n/a																			
6121.1	92	0	81.56	141.12	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	18.0	4	3.4	1	3.1	7	0.4	2	0	0.00	3.6
6201.1	6	510	162.27	29.99	qMBE*l	Mass Reduction	MBE	opalite	1.00	0.0	0	1200.3	5	1274.1	60	2051.6	69	635.6	179	504.9	126	334.1	676	88.8	188	6	486.80	1424.6
6221.1	6	511	161.77	29.49	QMBE*	Mass Reduction	MBE	opalite	1.00	0.0	0	183.7	1	583.9	41	4380.5	151	597.9	189	1416.7	379	259.5	688	*****	749	14	1554.40	4282.9
6241.1	6	512	161.27	30.49	MBEl	unanalyzed	unanalyzed	opalite	n/a																			
6261.1	6	513	160.77	28.99	BE*l	unanalyzed	unanalyzed	opalite	n/a																			
6281.1	6	514	162.27	31.99	q BE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	82.7	3	0.0	0	37.0	7	0.0	0	7.4	17	3.8	13	1	269.10	346.0
6301.1	6	515	163.27	29.49	M*BEl	Early thinning	mBE	opalite	1.00	601.6	0	1248.5	3	0.0	0	585.9	17	816.2	101	34.9	64	175.9	322	34.9	62	8	1523.00	1955.8
6321.1	6	516	161.77	27.49	mBE	Early thinning	BEl	opalite	1.00	0.0	0	0.0	0	0.0	0	56.3	1	12.8	6	41.6	9	11.5	24	15.7	36	0	0.00	91.7
6341.1	6	517	163.27	29.99	M*bEl	Mass Reduction	MB	opalite	1.00	0.0	0	794.5	4	87.9	7	1393.7	31	101.7	30	221.0	47	48.0	121	31.1	51	3	319.90	756.7
6361.1	6	518	159.77	28.99	mbE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	7.2	3	5.4	3	4.5	15	3.1	10	0	0.00	33.1

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Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
6381.1	6	519	159.77	31.99	mB	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	11.2	2	28.7	4	6.0	12	1.6	6	0	0.00	9.4
6401.1	87	520	92.70	128.09	E	unanalyzed	unanalyzed	opalite	n/a																			
6421.1	87	521	93.70	127.09	MBe	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	20.6	1	6.1	4	7.9	2	7.4	19	2.1	3	0	0.00	16.6
6441.1	87	522	95.70	127.59	M*B*e	Mass Reduction	qMB	opalite	n/a																			
6441.1	87	522	95.70	127.59	M*B*e	Mass Reduction	qMB	opalite	1.00	0.0	0	772.3	3	0.0	0	418.4	13	67.3	18	84.8	12	14.7	37	11.2	18	0	0.00	254.6
6441.1	87	522	95.70	127.59	MB	Mass Reduction	qMB	opalite	1.00	0.0	0	772.3	3	0.0	0	418.4	13	67.3	18	84.8	12	14.7	37	11.2	18	0	0.00	254.6
6461.1	87	523	96.20	126.59	be	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	2.5	1	3.1	1	2.7	8	1.1	3	0	0.00	2.0
6481.1	87	524	94.20	125.59	MBe	unanalyzed	unanalyzed	opalite	n/a																			
6501.1	87	525	92.70	124.09	e	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	4.7	2	7.0	2	2.5	7	2.0	2	0	0.00	5.9
6521.1	92	526	79.86	141.07	M*BE	unanalyzed	unanalyzed	opalite	n/a																			
6541.1	92	0	80.86	142.07	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	4.1	1	18.6	2	2.3	7	1.9	3	0	0.00	12.9
6561.1	92	0	79.86	143.07	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	5.1	1	1.2	1	4.2	7	2.1	4	0	0.00	37.2
6581.1	92	529	78.36	142.07	M E	unanalyzed	unanalyzed	opalite	n/a																			
6621.1	92	0	77.36	138.57	unanalyzed	Mass Reduction	MBE?	opalite	1.00	0.0	0	0.0	0	0.0	0	74.6	2	41.4	10	39.5	7	11.8	24	11.4	15	0	0.00	135.1
6641.1	92	532	81.36	140.07	MBe	unanalyzed	unanalyzed	opalite	n/a																			
6661.1	63	533	141.30	78.57	M	Mass Reduction	mBE	opalite	1.00																			
6661.1	63	533	141.30	78.57	MBEL*	Mass Reduction	mBE	opalite	1.00	0.0	0	0.0	0	93.7	3	9.7	1	28.6	10	42.6	11	16.2	36	8.1	10	0	0.00	99.6
6661.1	63	533	141.30	78.57	M	Mass Reduction	mBE	opalite	1.00	0.0	0	0.0	0	93.7	3	9.7	1	28.6	10	42.6	11	16.2	36	8.1	10	0	0.00	99.6
6661.2	63	533	141.30	78.57	too small	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	3.1	1	0.0	0	0.0	0	0.0	0	0	0.00	0.0
6681.1	63	534	140.80	76.57	mBE*l	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	36.5	2	22.2	1	32.1	10	14.3	5	26.0	51	10.6	20	0	0.00	37.9
6701.1	63	535	140.30	77.07	BE	Early thinning	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	18.8	8	13.6	5	12.2	34	5.0	13	0	0.00	1.2
6701.1	63	535	140.30	77.07	BE	Early thinning	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	18.8	8	13.6	5	12.2	34	5.0	13	0	0.00	1.2
6701.1	63	535	140.30	77.07	BE	Early thinning	too small	opalite	1.00																			
6701.2	63	0	140.30	77.07	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.3	1	0.0	0	0	0.00	0.0
6721.1	63	536	139.80	80.57	bEL	unanalyzed	unanalyzed	opalite	n/a																			
6741.1	63	537	137.80	80.07	EL	unanalyzed	unanalyzed	opalite	n/a																			
6761.1	63	538	137.30	78.57	MBE	unanalyzed	unanalyzed	opalite	n/a																			
6761.1	63	538	137.30	78.57	E	unanalyzed	unanalyzed	opalite	n/a																			
6781.1	63	539	139.30	76.07	MBE*	unanalyzed	unanalyzed	opalite	n/a																			
6801.1	38	540	101.72	110.21	MBe	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	26.4	1	6.4	1	12.2	2	2.2	2	0.3	1	0	0.00	21.7
6821.1	38	541	102.22	115.71	too small	unanalyzed	unanalyzed	opalite																				
6841.1	38	542	102.22	115.71	too small	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.5	1	0.7	2	0	0.00	8.9
6881.1	86	544	81.60	121.18	MB*E	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	67.6	2	52.6	2	18.7	5	47.3	10	16.5	23	2.9	7	0	0.00	0.0
6901.1	86	545	81.10	123.18	MB*EI	unanalyzed	unanalyzed	opalite	n/a																			
6921.1	86	546	79.60	121.18	mBE*l	Early thinning	BEL	opalite	1.00	0.0	0	0.0	0	24.3	1	150.2	6	106.2	31	238.3	54	79.4	178	74.9	154	0	0.00	44.2
6921.2	86	0	79.60	121.18	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.8	1	0.0	0	0	0.00	0.0
6941.1	86	547	80.10	123.18	MBEI	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	27.0	1	312.8	13	141.7	30	221.3	46	70.4	155	52.2	117	0	0.00	8.1
6961.1	86	548	79.10	123.68	M*BE	Mass Reduction	MBE	opalite	1.00	0.0	0	441.7	3	182.6	6	662.0	21	115.6	31	321.7	76	49.3	83	70.0	93	1	79.10	224.9
6981.1	86	549	79.10	125.18	MBE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	91.4	1	0.0	0	16.3	8	34.2	9	3.4	12	8.6	18	0	0.00	39.2

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
7001.1	86	550	78.10	124.68	qM*BE	unanalyzed	unanalyzed	opalite	n/a																			
7021.1	86	551	77.60	124.68	QM*bE	Mass Reduction	MBE	opalite	1.00	168.9	1	210.6	2	133.6	7	582.5	21	217.3	39	215.1	50	60.5	109	25.8	46	3	2426.40	3271.5
7041.1	86	552	77.60	121.68	MBe	unanalyzed	unanalyzed	opalite	n/a																			
7061.1	86	553	77.10	121.18	mBEl	unanalyzed	unanalyzed	opalite	n/a																			
7061.10	86	553	77.10	121.18	too small	unanalyzed	unanalyzed	opalite	n/a																			
7081.10	86	554	78.10	125.18	qMBE	unanalyzed	unanalyzed	opalite	n/a																			
7107.1	86	555	0.00	0.00	MBe	unanalyzed	unanalyzed	opalite	n/a																			
7121.1	63	556	137.30	80.07	mBE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	13.7	1	0.0	0	5.0	1	28.5	5	7.0	13	1.1	3	0	0.00	59.5
7141.1	63	557	137.30	78.07	M*bE	Mass Reduction	MB	opalite	1.00	0.0	0	166.4	1	49.5	3	402.7	12	37.6	7	24.2	8	13.0	40	19.9	36	0	0.00	258.0
7161.1	63	558	138.80	77.07	BE*l	unanalyzed	unanalyzed	opalite	n/a																			
7161.1	63	558	138.80	77.07	MBE	unanalyzed	unanalyzed	opalite	n/a																			
8001.2	105	566	140.71	73.86	mB*e	unanalyzed	unanalyzed	opalite	n/a																			
8021.2	105	567	140.71	74.86	mB*	unanalyzed	unanalyzed	opalite	n/a																			
8041.2	106	568	125.02	92.92	MBE	unanalyzed	unanalyzed	opalite	n/a																			
8061.2	106	569	125.02	93.92	MBE	unanalyzed	unanalyzed	opalite	n/a																			
8081.2	107	570	125.31	98.43	M*Be	unanalyzed	unanalyzed	opalite	n/a																			
8101.2	107	571	124.31	98.43	BE*	unanalyzed	unanalyzed	opalite	n/a																			
8121.3	108	572	122.77	122.43	B*E	unanalyzed	unanalyzed	opalite	n/a																			
8141.4	108	573	122.77	123.42	BE*	unanalyzed	unanalyzed	opalite	n/a																			
8161.2	109	574	102.55	102.22	C*mel	unanalyzed	unanalyzed	opalite	n/a																			
8181.2	109	575	102.55	103.22	bE 109	unanalyzed	unanalyzed	opalite	n/a																			
8201.2	110	576	105.94	110.68	BE	unanalyzed	unanalyzed	opalite	n/a																			
8221.2	110	577	105.94	111.68	BE	unanalyzed	unanalyzed	opalite	n/a																			
8241.1	106	578	124.02	93.92	MBE	unanalyzed	unanalyzed	opalite	n/a																			
8261.1	106	579	125.02	91.92	MB*E*l	unanalyzed	unanalyzed	opalite	n/a																			
8281.1	107	580	125.31	97.43	mbE*	unanalyzed	unanalyzed	opalite	n/a																			
8301.1	107	581	126.31	98.43	M*BE	unanalyzed	unanalyzed	opalite	n/a																			
8321.1	109	582	101.55	103.22	C* E	unanalyzed	unanalyzed	opalite	n/a																			
8341.1	102	588	66.64	47.88	QMbe	Early thinning	MB	opalite	0.13	852.5	3	0.0	0	123.4	8	368.7	11	137.1	38	74.3	16	68.2	149	28.2	45	8	3151.30	4064.0
8341.14	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.5	1	0.5	1	0	0.00	0.3
8341.15	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	32.9	1	0.0	0	7.1	2	0.0	0	1.5	3	0.0	0	0	0.00	0.0
8342.18	102	588	66.64	47.88	MBE*	Mass Reduction	MB	opalite	0.13	94.7	1	257.6	3	210.0	8	514.3	17	100.7	22	134.5	27	30.3	62	38.2	48	9	1169.40	1422.8
8342.19	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.4	1	0.5	1	0.0	0	0.0	0	0	0.00	0.0
8342.20	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.1	1	0.0	0	0	0.00	0.0
8342.21			66.64	47.88				jasper	1.00	0.0	0	0.0	0	12.0	1	0.0	0	1.5	1	0.0	0	0.0	0	0.0	0	0	0.00	46.0
8343.1	102	588	66.64	47.88	QMbe	Early thinning	MBE	opalite	0.13	162.7	1	498.3	1	176.7	5	256.0	9	127.5	33	43.1	11	99.4	201	10.0	20	6	1039.80	1501.8
8343.3	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	6.4	1	0.0	0	1.7	5	0.0	0	0	0.00	0.0
8343.4	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	3.4	4	0.0	0	0	0.00	0.0
8344.1	102	588	66.64	47.88	QMbe	Mass Reduction	mBE	opalite	1.00	138.4	1	396.6	1	219.4	8	400.3	14	140.8	35	106.0	25	78.9	170	32.3	67	7	3067.80	4197.9

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
8344.12	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.4	3	1.4	3	0	0.00	5.0
8345.1	102	588	66.64	47.88	Q*Mbe	unanalyzed	unanalyzed	opalite	n/a																			
8345.2	102	0	66.64	47.88	unanalyzed	Early thinning	BEI	opalite	0.25	407.1	2	244.7	2	176.6	7	198.0	10	219.5	63	107.2	20	258.8	507	27.3	64	2	462.80	3800.0
8345.4	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	13.0	1	1.5	1	2.1	1	2.4	8	0.6	3	0	0.00	0.0
8346.1	102	588	66.64	47.88	Q*mBE	Early thinning	EI	opalite	1.00	0.0	0	0.0	0	87.5	6	164.9	7	126.6	34	172.1	38	195.6	386	71.7	128	5	429.80	1543.9
8346.2	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	5.5	1	0.0	0	1.4	1	0.0	0	0	0.00	0.0
8346.3	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.3	3	0.0	0	0	0.00	0.0
8347.1	102	588	66.64	47.88	Q*Mbe	Early thinning	BE	opalite	0.25	57.7	1	0.0	0	131.3	7	399.9	10	133.0	30	73.2	18	86.2	202	33.3	75	10	1392.00	0.0
8347.2	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	9.0	4	0.0	0	12.2	17	0.0	0	0	0.00	0.0
8348.1	102	588	66.64	47.88	Q*MbE	unanalyzed	unanalyzed	opalite	n/a																			
8348.2	102	0	66.64	47.88	unanalyzed	Early thinning	BEI	opalite	1.00	0.0	0	140.2	1	194.0	9	253.2	10	245.0	66	116.2	29	192.4	415	71.9	160	14	1022.30	5600.0
8349.2	102	0	66.64	47.88	unanalyzed	Early thinning	MBe	opalite	0.25	0.0	0	266.5	1	36.9	1	108.5	4	34.2	11	26.4	8	30.0	65	5.3	12	5	338.00	634.6
8349.3	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	10.7	3	0.0	0	11.1	18	0.0	0	0	0.00	0.0
8349.4	102	0	66.64	47.88	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	7.3	1	0.0	0	0.5	1	0.0	0	0	0.00	0.0
8381.1	102	590	66.09	44.70	qmBE	Early thinning	MBE	opalite	1.00	0.0	0	131.6	1	118.1	2	300.0	15	170.3	38	297.2	56	81.1	79	67.0	97	0	0.00	574.0
8382.1	102	590	66.09	44.70	Q*MBE	Mass Reduction	BE	opalite	0.50	0.0	0	206.1	1	115.1	6	598.6	24	120.7	27	276.3	65	69.0	206	82.4	159	0	0.00	6600.0
8383.1	102	588	66.09	44.70	QMBE*l	Mass Reduction	MBe	opalite	0.13	184.2	4	339.0	2	474.4	21	264.4	14	252.7	55	196.8	47	42.9	72	67.7	174	0	0.00	2274.5
8383.2	102	0	66.09	44.70	unanalyzed	N TOO SMALL	too small	other	1.00	110.0	1	0.0	0	10.7	1	0.0	0	9.3	2	0.0	0	6.0	5	0.0	0	0	0.00	0.0
8384.1	102	588	66.09	44.70	qMbE*	Early thinning	BEI	opalite	0.50	0.0	0	133.2	1	72.0	5	171.9	12	131.3	31	123.1	23	99.2	142	48.9	105	0	0.00	1120.6
8384.2	102	0	66.09	44.70	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	6.7	1	0.0	0	6.0	3	0.0	0	3.2	7	0.0	0	0	0.00	0.0
8384.3	102	0	66.09	44.70	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.9	1	0.0	0	0.0	0	0	0.00	0.0
8385.1	102	590	66.09	44.70	QM*Be	Mass Reduction	MBe	opalite	0.25	0.0	0	404.5	2	502.0	22	327.2	16	124.1	30	151.1	39	92.5	232	30.8	59	0	0.00	8000.0
8386.1	102	590	66.09	44.70	Q*mbE	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	0.0	0	62.4	1	23.8	7	63.5	16	12.8	32	24.3	34	3	300.70	780.6
8386.2	102	0	66.09	44.70	unanalyzed	N TOO SMALL	too small	other	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.9	2	0.0	0	0	0.00	17.7
8387.1	102	590	66.09	44.70	Q*MBE	Mass Reduction	MBe	opalite	0.50	0.0	0	225.9	3	13.5	1	253.2	8	24.3	10	60.3	13	16.7	46	15.9	38	0	0.00	13000.0
8388.1	102	590	66.09	44.70	Q*MBE	Early thinning	BEI	opalite	1.00	0.0	0	0.0	0	406.0	16	227.3	11	235.0	60	187.0	47	171.0	418	53.0	96	17	2411.50	3974.7
8389.1	102	590	66.09	44.70	QMBE	Mass Reduction	mBE	opalite	0.06	0.0	0	0.0	0	141.7	5	214.8	11	58.3	16	43.7	14	35.2	94	16.3	37	3	555.80	969.1
8390.1	102	590	66.09	44.70	QMB	Early thinning	BE	opalite	1.00	0.0	0	162.9	1	21.2	1	156.4	8	45.7	16	84.8	22	63.9	154	23.8	46	1	57.90	593.1
8391.1	102	0	66.09	44.70	unanalyzed	Early thinning	BE	opalite	0.50	0.0	0	267.0	2	217.7	11	92.3	6	153.0	39	78.9	18	68.0	166	16.3	42	29	5412.70	7447.1
8392.4	102	590	66.09	44.70	qM*Be	Mass Reduction	MBe	opalite	0.06	513.5	1	141.8	1	276.8	11	303.2	8	117.0	29	26.3	8	64.8	134	18.6	34	10	2024.60	4118.2
8392.5	102	0	66.09	44.70	unanalyzed	N TOO SMALL	too small	basalt	1.00	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	1.5	1	0	0.00	0.0
8393.1	102	0	66.09	44.70	unanalyzed	Early thinning	BE	opalite	1.00	0.0	0	0.0	0	6.1	1	102.6	5	11.5	5	45.1	10	15.8	44	12.5	31	7	1092.70	2088.8
8394.1	102	0	66.09	44.70	unanalyzed	Mass Reduction	BE	opalite	1.00	0.0	0	0.0	0	39.0	1	49.5	1	23.9	8	3.1	1	9.2	30	7.1	16	14	1715.20	3011.6
8395.1	102	0	66.09	44.70	unanalyzed	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	47.2	2	10.5	1	13.4	5	5.3	3	9.0	24	2.4	8	0	0.00	352.9
8396.1	102	0	66.09	44.70	unanalyzed	Early thinning	MB	opalite	1.00	457.5	1	288.4	1	115.9	3	133.6	3	121.2	11	33.5	3	42.4	60	0.0	0	4	542.30	1207.5
8397.1	102	590	66.09	44.70	QMBe	Early thinning	BE	opalite	1.00	148.3	1	395.2	2	102.4	3	167.5	5	93.4	15	64.5	10	89.9	150	30.8	48	6	676.70	1395.2
8398.1	102	590	66.09	44.70	qMBe	Early thinning	BE	opalite	1.00	57.0	1	0.0	0	5.5	1	152.5	2	10.8	5	74.6	11	26.8	69	28.1	55	1	430.20	1519.7
9141.1	63	507	139.28	78.35	BEL*	unanalyzed	unanalyzed	opalite	n/a																			
9141.1	63	507	139.28	78.35	MBE*	unanalyzed	unanalyzed	opalite	n/a																			

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table 1. Debitage data: excavation units, lithic inventories, trench samples.

ID	Feature	Unit	N	E	Technological analysis result	Mass analysis result	Weibull analysis result	Raw material	Sample fraction	G0 Flake fragments wt.(g)	n	G0 Flakes w/ platforms wt.(g)	n	G1 Flake fragments wt.(g)	n	G1 Flakes w/ platforms wt.(g)	n	G2 Flake fragments wt.(g)	n	G2 Flakes w/ platforms wt.(g)	n	G3 Flake fragments wt.(g)	n	G3 Flakes w/ platforms wt.(g)	n	G0 Angular debris n	wt.(g)	>G0 Angular debris wt. (g)
9161.1	63	508	138.48	78.95	mBE	Mass Reduction	MBe	opalite	1.00																			
9161.1	63	508	138.48	78.95	b L	Mass Reduction	MBe	opalite	1.00	0.0	0	0.0	0	0.0	0	66.5	4	15.2	5	21.4	9	9.8	23	6.1	17	0	0.00	34.4
9161.1	63	508	138.48	78.95	mBE	Mass Reduction	MBe	opalite	1.00	0.0	0	0.0	0	0.0	0	66.5	4	15.2	5	21.4	9	9.8	23	6.1	17	0	0.00	34.4
9181.1	63	509	137.28	76.11	mBE	N TOO SMALL	too small	opalite	1.00	0.0	0	0.0	0	0.0	0	0.0	0	105.2	6	1.3	1	8.3	14	9.0	5	1	350.90	357.1
9241.1	106	578	124.02	93.92	MBE	unanalyzed	unanalyzed	opalite	n/a																			

KEY: Q = quarry debris, M = mass reduction, B = blank preparation E = early biface thinning L = late biface thinning

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5001	1	142.00	28.00	opalite	22	15.5	0	0.0	23.6
5002	1	147.00	25.00	opalite	18	90.6	0	0.0	29.3
5003	1	147.00	30.00	opalite	5	9.0	0	0.0	14.4
5004	1	146.00	33.00	opalite	9	6.8	0	0.0	20.2
5005	1	135.00	26.00	opalite	27	861.0	0	0.0	121.4
5006	1	138.00	26.00	opalite	18	33.4	0	0.0	23.0
5007	1	130.00	38.00	opalite	20	329.1	0	0.0	58.1
5008	1	138.00	37.00	opalite	8	36.0	0	0.0	4.4
5009	1	153.00	23.00	opalite	2	0.5	0	0.0	6.9
5010	1	153.00	26.00	opalite	9	16.3	0	0.0	45.1
5011	1	155.00	31.00	opalite	3	11.2	0	0.0	15.4
5012	1	150.00	38.00	opalite	4	35.0	0	0.0	4.9
5013	1	161.00	24.00	opalite	5	3.9	0	0.0	51.1
5014	1	163.00	27.00	opalite	1	0.1	0	0.0	1.9
5015	1	162.00	33.00	opalite	4	0.6	0	0.0	7.6
5016	1	163.00	38.00	opalite	0	0.0	0	0.0	26.7
5017	1	134.00	5.00	opalite	23	37.5	0	0.0	47.7
5018	1	136.00	9.00	opalite	92	278.2	0	0.0	42.5
5019	1	132.00	14.00	opalite	47	60.8	0	0.0	264.8
5020	1	138.00	19.00	opalite	44	187.1	4	199.1	396.1
5021	1	147.00	10.00	opalite	63	102.4	5	299.8	484.7
5022	1	149.00	17.00	opalite	18	24.6	0	0.0	30.6
5023	1	142.00	9.00	opalite	36	68.7	2	59.6	115.5
5024	1	146.00	2.00	opalite	19	307.6	2	125.2	184.7
5025	1	150.00	1.00	opalite	8	12.5	0	0.0	7.3
5026	1	159.00	5.00	opalite	37	252.0	0	0.0	77.9
5028	1	161.00	6.00	opalite	1	0.4	0	0.0	36.1
5029	1	160.00	15.00	opalite	6	1.2	0	0.0	40.0
5031	1	155.00	16.00	opalite	7	29.9	0	0.0	15.2
5032	1	158.00	12.00	opalite	0	0.0	0	0.0	53.7
5033	1	117.00	20.00	opalite	48	147.4	0	0.0	171.8
5034	1	111.00	26.00	opalite	34	330.1	0	0.0	181.6
5035	1	117.00	32.00	opalite	44	202.1	0	0.0	292.0
5036	1	110.00	36.00	opalite	42	278.5	3	136.5	459.0

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5037	1	120.00	33.00	opalite	32	21.7	2	186.7	298.0
5038	1	122.00	39.00	opalite	128	595.8	0	0.0	100.3
5039	1	125.00	21.00	opalite	26	23.7	0	0.0	74.0
5040	1	123.00	25.00	opalite	54	190.0	0	0.0	352.6
5041	1	163.00	40.00	opalite	2	1.7	0	0.0	5.1
5042	1	162.00	46.00	opalite	0	0.0	0	0.0	6.3
5045	1	155.00	49.00	opalite	8	8.0	0	0.0	4.7
5046	1	158.00	48.00	opalite	17	22.2	0	0.0	5.2
5047	1	151.00	53.00	opalite	2	5.1	0	15.6	0.0
5048	1	152.00	55.00	opalite	1	0.8	0	0.0	19.6
5049	1	140.00	48.00	opalite	8	15.5	0	0.0	22.0
5050	1	143.00	49.00	opalite	10	20.2	0	0.0	37.0
5051	1	143.00	56.00	opalite	3	14.9	0	0.0	39.6
5052	1	149.00	57.00	opalite	1	1.6	0	0.0	14.4
5053	1	130.00	46.00	opalite	6	15.2	0	0.0	5.8
5054	1	138.00	48.00	opalite	9	6.6	0	0.0	7.3
5055	1	133.00	56.00	opalite	4	28.1	0	0.0	60.7
5056	1	137.00	59.00	opalite	4	3.2	0	0.0	6.4
5057	1	122.00	53.00	opalite	11	28.4	0	0.0	28.5
5058	1	122.00	56.00	opalite	8	12.9	0	0.0	20.4
5059	1	120.00	49.00	opalite	26	383.7	2	391.5	449.7
5060	1	120.00	43.00	opalite	28	300.9	2	287.1	160.7
5061	1	114.00	47.00	opalite	67	262.2	0	0.0	163.2
5062	1	112.00	49.00	opalite	85	282.0	0	0.0	483.3
5063	1	111.00	56.00	opalite	34	67.4	0	0.0	39.9
5064	1	112.00	58.00	opalite	26	22.5	0	0.0	41.3
5065	1	101.00	53.00	opalite	8	77.9	0	0.0	153.9
5066	1	103.00	53.00	opalite	48	298.2	1	284.3	357.1
5067	1	104.00	66.00	opalite	60	772.1	1	143.7	228.2
5068	1	106.00	67.00	opalite	43	238.3	0	0.0	102.4
5069	1	98.00	54.00	opalite	20	87.1	0	0.0	13.3
5070	1	91.00	58.00	opalite	79	181.9	0	0.0	99.5
5071	1	95.00	60.00	opalite	119	348.6	0	0.0	180.2
5072	1	99.00	65.00	opalite	128	463.1	0	0.0	64.2

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5073	1	88.00	50.00	opalite	142	346.5	0	0.0	263.2
5074	1	88.00	56.00	opalite	70	196.1	0	0.0	54.0
5075	1	81.00	65.00	opalite	107	208.1	0	0.0	153.4
5076	1	85.00	69.00	opalite	34	92.1	0	0.0	57.9
5077	1	85.00	70.00	opalite	171	268.9	0	0.0	108.4
5078	1	83.00	72.00	opalite	57	689.7	0	0.0	208.2
5081	1	97.00	73.00	opalite	66	99.1	0	0.0	65.2
5082	1	96.00	71.00	opalite	56	119.8	0	0.0	67.1
5084	1	109.00	70.00	opalite	18	37.0	0	0.0	10.7
5085	1	107.00	82.00	opalite	9	9.7	0	0.0	26.3
5086	1	107.00	89.00	opalite	19	17.5	0	0.0	9.1
5088	1	95.00	89.00	opalite	72	101.6	0	0.0	21.0
5089	1	113.00	60.00	opalite	16	55.5	0	0.0	27.1
5090	1	118.00	67.00	opalite	7	2.4	0	0.0	2.9
5091	1	122.00	63.00	opalite	2	6.6	0	0.0	0.0
5092	1	128.00	60.00	opalite	3	7.3	0	0.0	3.2
5094	1	122.00	79.00	opalite	13	38.4	0	0.0	1.5
5096	1	114.00	79.00	opalite	23	57.7	0	0.0	11.8
5097	1	93.00	92.00	opalite	41	231.7	2	60.8	100.8
5098	1	95.00	95.00	opalite	30	52.8	0	0.0	19.4
5099	1	92.00	105.00	opalite	4	6.5	0	0.0	2.0
5100	1	99.00	102.00	opalite	6	11.7	0	0.0	16.7
5101	1	76.00	115.00	opalite	49	262.1	0	0.0	12.1
5102	1	72.00	117.00	opalite	8	10.3	0	0.0	3.0
5103	1	75.00	125.00	opalite	5	1.9	0	0.0	2.7
5104	1	78.00	124.00	opalite	10	28.8	0	0.0	4.1
5105	1	84.00	115.00	opalite	3	1.3	0	0.0	7.5
5106	1	86.00	119.00	opalite	3	9.1	0	0.0	19.2
5107	1	81.00	127.00	opalite	4	1.2	0	0.0	3.9
5108	1	86.00	124.00	opalite	1	6.9	0	0.0	14.4
5109	1	70.00	91.00	opalite	14	114.9	0	0.0	34.1
5111	1	83.00	99.00	opalite	28	65.1	0	0.0	36.7
5113	1	73.00	101.00	opalite	34	326.1	3	126.5	168.8
5114	1	72.00	109.00	opalite	9	35.7	0	0.0	33.7

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5115	1	82.00	107.00	opalite	17	141.0	1	27.6	28.3
5116	1	83.00	109.00	opalite	22	36.8	0	0.0	4.4
5117	1	50.00	98.00	opalite	13	22.7	0	0.0	29.2
5118	1	51.00	98.00	opalite	15	21.7	0	0.0	81.5
5119	1	60.00	95.00	opalite	23	86.7	1	10.9	41.3
5120	1	62.00	99.00	opalite	26	50.8	0	0.0	21.6
5121	1	50.00	103.00	opalite	19	49.0	0	0.0	14.7
5122	1	59.00	105.00	opalite	0	0.0	1	494.6	511.2
5123	1	63.00	104.00	opalite	18	99.3	0	0.0	54.7
5124	1	68.00	106.00	opalite	43	97.6	0	0.0	32.7
5125	1	56.00	117.00	opalite	31	125.7	4	300.5	417.2
5131	1	68.00	124.00	opalite	19	28.3	0	0.0	8.5
5132	1	69.00	125.00	opalite	12	21.2	0	0.0	10.6
5133	1	31.00	95.00	opalite	13	13.1	0	0.0	56.7
5134	1	36.00	91.00	opalite	9	10.3	0	0.0	15.2
5135	1	44.00	92.00	opalite	49	93.7	0	0.0	141.0
5136	1	40.00	99.00	opalite	37	56.3	0	0.0	25.1
5137	1	34.00	100.00	opalite	6	25.5	0	0.0	43.1
5138	1	36.00	108.00	opalite	67	217.8	1	44.3	181.5
5139	1	44.00	105.00	opalite	31	19.7	0	0.0	52.9
5140	1	45.00	105.00	opalite	51	75.5	1	47.2	99.2
5141	1	42.00	50.00	opalite	31	83.2	0	0.0	47.6
5142	1	47.00	53.00	opalite	14	15.0	0	0.0	91.6
5143	1	47.00	64.00	opalite	19	26.0	0	0.0	24.3
5144	1	47.00	68.00	opalite	7	12.2	0	0.0	69.7
5144	2	47.00	68.00	jasper	2	6.2	0	0.0	0.0
5145	1	57.00	55.00	opalite	56	184.3	1	29.4	229.7
5146	1	58.00	55.00	opalite	29	53.5	2	142.6	337.8
5147	1	54.00	60.00	opalite	8	9.3	0	0.0	83.4
5148	1	51.00	68.00	opalite	21	53.9	0	0.0	92.3
5149	1	62.00	52.00	opalite	43	170.6	5	270.3	466.0
5150	1	68.00	51.00	opalite	62	337.4	2	82.5	337.2
5151	1	64.00	63.00	opalite	28	132.8	0	0.0	184.8
5152	1	64.00	65.00	opalite	68	247.6	1	23.9	233.3

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5153	1	73.00	51.00	opalite	84	305.4	0	0.0	75.2
5154	1	78.00	59.00	opalite	107	211.1	0	0.0	358.3
5155	1	78.00	69.00	opalite	129	211.9	0	0.0	116.1
5156	1	79.00	61.00	opalite	99	384.2	1	30.1	131.0
5157	1	79.00	70.00	opalite	181	416.5	0	0.0	223.0
5158	1	75.00	72.00	opalite	57	314.4	4	255.9	395.3
5159	1	78.00	84.00	opalite	70	165.0	0	0.0	194.4
5160	1	74.00	86.00	opalite	43	244.1	3	122.9	330.7
5161	1	61.00	84.00	opalite	43	81.0	0	0.0	194.4
5162	1	62.00	89.00	opalite	24	31.4	0	0.0	45.1
5163	1	68.00	73.00	opalite	154	237.0	0	0.0	120.7
5164	1	67.00	74.00	opalite	80	180.0	0	0.0	166.0
5165	1	44.00	76.00	opalite	16	91.3	0	0.0	27.6
5166	1	43.00	78.00	opalite	31	49.0	1	51.1	137.4
5167	1	43.00	84.00	opalite	39	73.7	0	0.0	182.4
5168	1	44.00	84.00	opalite	45	154.4	0	0.0	190.5
5169	1	56.00	77.00	opalite	20	62.2	0	0.0	63.9
5170	1	51.00	72.00	opalite	11	15.6	0	0.0	14.7
5171	1	55.00	83.00	opalite	16	20.1	0	0.0	70.0
5172	1	57.00	82.00	opalite	15	13.0	0	0.0	154.4
5173	1	23.00	54.00	opalite	20	68.1	0	0.0	144.0
5174	1	21.00	56.00	opalite	5	11.8	0	0.0	137.4
5175	1	35.00	52.00	opalite	10	61.8	1	461.8	575.3
5176	1	38.00	53.00	opalite	26	169.6	3	631.2	665.5
5177	1	39.00	63.00	opalite	48	497.1	0	0.0	102.7
5178	1	36.00	64.00	opalite	28	895.2	0	0.0	466.6
5179	1	25.00	61.00	opalite	11	41.0	0	0.0	115.8
5180	1	22.00	62.00	opalite	12	341.6	0	0.0	148.1
5181	1	29.00	70.00	opalite	44	617.2	0	0.0	462.1
5182	1	23.00	77.00	opalite	8	11.8	0	0.0	23.8
5183	1	37.00	75.00	opalite	17	59.9	0	0.0	108.6
5184	1	35.00	78.00	opalite	35	21.0	0	0.0	49.0
5185	1	38.00	85.00	opalite	21	46.3	0	0.0	60.4
5186	1	31.00	84.00	opalite	29	81.1	0	0.0	52.6

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5187	1	28.00	83.00	opalite	19	65.7	0	0.0	56.2
5188	1	21.00	89.00	opalite	28	65.8	0	0.0	46.1
5189	1	25.00	90.00	opalite	14	34.0	0	0.0	40.4
5190	1	29.00	99.00	opalite	7	8.0	0	0.0	79.4
5191	1	23.00	104.00	opalite	0	0.0	0	0.0	10.9
5192	1	25.00	106.00	opalite	6	6.1	0	0.0	60.7
5193	1	23.00	114.00	opalite	7	6.7	0	0.0	81.5
5194	1	28.00	119.00	opalite	17	61.0	0	0.0	90.0
5195	1	23.00	128.00	opalite	16	67.9	0	0.0	112.5
5196	1	29.00	127.00	opalite	37	96.5	0	0.0	46.4
5197	1	38.00	110.00	opalite	30	172.6	0	0.0	339.3
5198	1	33.00	115.00	opalite	45	167.9	0	0.0	313.6
5199	1	45.00	119.00	opalite	81	222.3	0	0.0	91.9
5200	1	46.00	119.00	opalite	167	384.5	0	0.0	195.1
5201	1	102.00	102.00	opalite	5	8.5	0	0.0	2.5
5202	1	102.00	107.00	opalite	10	20.8	0	0.0	15.8
5203	1	104.00	92.00	opalite	7	26.3	0	0.0	8.3
5204	1	106.00	92.00	opalite	5	36.0	0	0.0	6.5
5205	1	90.00	111.00	opalite	7	3.0	0	0.0	4.5
5206	1	94.00	111.00	opalite	0	0.0	0	0.0	2.4
5207	1	101.00	117.00	opalite	1	0.2	0	0.0	0.0
5208	1	104.00	116.00	opalite	3	0.8	0	0.0	0.0
5209	1	108.00	125.00	opalite	1	5.8	0	0.0	0.0
5210	1	109.00	121.00	opalite	3	8.5	0	0.0	0.0
5211	1	97.00	121.00	opalite	6	2.7	0	0.0	0.0
5212	1	97.00	124.00	opalite	4	2.8	0	0.0	0.0
5216	1	146.00	67.00	opalite	2	1.8	0	0.0	0.0
5217	1	140.00	77.00	opalite	1	0.4	0	0.0	7.9
5218	1	141.00	78.00	opalite	3	4.0	0	0.0	4.8
5219	1	133.00	77.00	opalite	4	8.0	0	0.0	8.4
5220	1	137.00	74.00	opalite	7	11.0	0	0.0	9.0
5222	1	154.00	65.00	opalite	2	3.2	0	0.0	1.1
5223	1	163.00	63.00	opalite	1	1.7	0	0.0	0.0
5227	1	157.00	79.00	opalite	1	1.2	0	0.0	0.0

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5228	1	153.00	77.00	opalite	11	33.6	0	0.0	19.3
5229	1	113.00	82.00	opalite	10	21.7	0	0.0	5.1
5230	1	116.00	80.00	opalite	7	4.1	0	0.0	0.0
5231	1	129.00	85.00	opalite	11	21.4	0	0.0	6.0
5232	1	128.00	89.00	opalite	7	4.4	0	0.0	0.0
5233	1	128.00	94.00	opalite	4	3.1	0	0.0	3.0
5234	1	127.00	96.00	opalite	8	26.9	0	0.0	1.8
5235	1	117.00	98.00	opalite	8	13.1	0	0.0	58.7
5236	1	113.00	97.00	opalite	13	23.8	0	0.0	20.4
5237	1	136.00	81.00	opalite	2	0.8	0	0.0	0.0
5238	1	137.00	88.00	opalite	1	0.6	0	0.0	10.6
5239	1	134.00	93.00	opalite	1	0.7	0	0.0	0.0
5240	1	132.00	98.00	opalite	3	1.8	0	0.0	0.5
5243	1	147.00	81.00	opalite	0	0.0	0	0.0	33.9
5244	1	141.00	85.00	opalite	3	1.0	0	0.0	0.0
5246	1	156.00	86.00	opalite	1	2.4	0	0.0	0.0
5250	1	167.00	91.00	opalite	1	2.6	0	0.0	6.4
5251	1	164.00	88.00	opalite	1	1.2	0	0.0	1.2
5252	1	166.00	86.00	opalite	1	5.5	0	0.0	0.0
5256	1	165.00	119.00	opalite	1	1.1	0	0.0	0.0
5258	1	150.00	118.00	opalite	2	1.6	0	0.0	0.0
5259	1	156.00	106.00	opalite	2	14.2	0	0.0	14.0
5261	1	148.00	104.00	opalite	1	0.4	0	0.0	0.8
5265	1	131.00	111.00	opalite	2	7.5	0	0.0	0.0
5266	1	133.00	119.00	opalite	2	1.7	0	0.0	0.0
5267	1	138.00	102.00	opalite	1	5.2	0	0.0	0.0
5268	1	133.00	100.00	opalite	5	14.9	0	0.0	5.5
5269	1	126.00	108.00	opalite	3	4.0	0	0.0	0.0
5270	1	125.00	106.00	opalite	2	0.8	0	0.0	0.0
5271	1	128.00	114.00	opalite	2	4.3	0	0.0	0.0
5272	1	127.00	116.00	opalite	2	2.5	0	0.0	0.0
5275	1	118.00	104.00	opalite	4	7.0	0	0.0	0.3
5276	1	110.00	104.00	opalite	2	1.2	0	0.0	0.0
5277	1	41.00	9.00	opalite	4	24.4	0	0.0	35.2

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5278	1	45.00	9.00	opalite	4	24.4	0	0.0	34.9
5279	1	50.00	8.00	opalite	6	62.1	0	0.0	0.0
5280	1	58.00	8.00	opalite	17	101.7	0	0.0	38.6
5281	1	60.00	3.00	opalite	4	21.2	0	0.0	11.6
5282	1	69.00	4.00	opalite	13	124.0	0	0.0	41.4
5283	1	112.00	122.00	opalite	3	7.6	0	0.0	0.0
5285	1	124.00	123.00	opalite	1	1.2	0	0.0	0.0
5286	1	123.00	122.00	opalite	1	3.6	0	0.0	0.0
5287	1	137.00	122.00	opalite	1	3.4	0	0.0	1.2
5288	1	139.00	129.00	opalite	1	0.3	0	0.0	6.2
5289	1	141.00	127.00	opalite	5	7.5	0	0.0	1.5
5293	1	166.00	124.00	opalite	1	5.1	0	0.0	0.0
5294	1	163.00	126.00	opalite	0	0.0	0	0.0	1.3
5295	1	165.00	139.00	opalite	0	0.0	0	0.0	4.3
5296	1	160.00	135.00	opalite	3	4.0	0	0.0	0.0
5297	1	156.00	136.00	opalite	0	0.0	0	0.0	2.8
5298	1	150.00	131.00	opalite	1	2.4	0	0.0	0.0
5300	1	153.00	143.00	opalite	1	2.0	0	0.0	0.0
5301	1	41.00	125.00	opalite	74	96.9	0	0.0	136.2
5302	1	45.00	122.00	opalite	92	229.0	0	0.0	92.0
5302	2	45.00	122.00	other	1	1.0	0	0.0	0.0
5303	1	33.00	126.00	opalite	53	126.1	0	0.0	142.0
5304	1	38.00	128.00	opalite	70	120.1	0	0.0	248.2
5305	1	70.00	4.00	opalite	11	23.7	0	0.0	83.9
5306	1	71.00	0.00	opalite	33	109.0	0	0.0	244.6
5307	1	87.00	1.00	opalite	6	3.2	0	0.0	72.7
5308	1	85.00	6.00	opalite	11	23.6	1	36.5	113.0
5309	1	72.00	11.00	opalite	35	104.4	0	0.0	116.2
5310	1	71.00	12.00	opalite	42	98.4	0	0.0	145.1
5311	1	85.00	14.00	opalite	24	576.8	10	1232.9	1583.5
5312	1	87.00	15.00	opalite	26	318.7	0	0.0	664.2
5313	1	91.00	2.00	opalite	6	3.7	0	0.0	318.7
5314	1	99.00	4.00	opalite	5	14.7	0	0.0	57.3
5315	1	101.00	4.00	opalite	4	1.8	0	0.0	18.1

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5316	1	100.00	7.00	opalite	7	20.6	0	0.0	42.7
5317	1	101.00	14.00	opalite	14	48.4	0	0.0	27.7
5318	1	104.00	16.00	opalite	34	155.4	0	0.0	76.1
5319	1	90.00	12.00	opalite	14	27.0	0	0.0	34.9
5320	1	91.00	19.00	opalite	50	91.8	0	0.0	85.2
5321	1	111.00	3.00	opalite	16	17.4	0	0.0	34.8
5322	1	119.00	9.00	opalite	17	36.4	0	0.0	15.3
5323	1	120.00	1.00	opalite	28	85.0	0	0.0	31.0
5324	1	121.00	0.00	opalite	10	7.0	0	0.0	44.4
5325	1	110.00	18.00	opalite	62	172.3	0	0.0	211.3
5326	1	118.00	16.00	opalite	33	60.1	0	0.0	160.9
5327	1	122.00	19.00	opalite	21	24.5	0	0.0	136.1
5328	1	124.00	19.00	opalite	26	43.5	0	0.0	90.3
5329	1	72.00	20.00	opalite	15	23.6	0	0.0	18.0
5330	1	79.00	23.00	opalite	21	60.4	0	0.0	9.0
5331	1	88.00	29.00	opalite	34	203.7	1	17.3	106.8
5332	1	89.00	29.00	opalite	23	95.0	3	233.9	297.3
5333	1	75.00	30.00	opalite	36	55.7	1	49.1	61.5
5334	1	77.00	35.00	opalite	30	153.0	2	44.0	79.8
5335	1	80.00	35.00	opalite	10	11.4	2	42.7	48.2
5336	1	89.00	33.00	opalite	35	154.4	0	0.0	73.7
5337	1	97.00	20.00	opalite	25	64.1	0	0.0	16.6
5338	1	99.00	26.00	opalite	50	167.9	0	0.0	12.1
5339	1	106.00	24.00	opalite	14	153.0	0	0.0	0.0
5340	1	109.00	27.00	opalite	47	97.0	1	73.7	82.2
5341	1	96.00	34.00	opalite	95	195.2	0	0.0	98.4
5342	1	96.00	37.00	opalite	96	453.0	0	0.0	82.5
5343	1	100.00	36.00	opalite	19	315.5	0	0.0	0.0
5344	1	102.00	39.00	opalite	97	381.2	0	0.0	25.0
5345	1	71.00	44.00	opalite	45	78.3	0	0.0	33.1
5346	1	79.00	41.00	opalite	51	245.6	3	46.5	95.0
5347	1	85.00	43.00	opalite	23	58.8	0	0.0	0.0
5348	1	87.00	42.00	opalite	90	188.6	0	0.0	9.7
5349	1	92.00	44.00	opalite	38	82.7	2	251.0	258.0

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5350	1	97.00	48.00	opalite	107	662.4	0	0.0	6.8
5351	1	104.00	41.00	opalite	106	351.2	2	114.6	121.6
5352	1	109.00	48.00	opalite	41	383.0	0	0.0	256.5
5353	1	8.00	30.00	opalite	6	11.8	1	165.5	195.0
5354	1	7.00	37.00	opalite	39	69.1	2	139.8	183.9
5355	1	15.00	33.00	opalite	3	64.3	0	0.0	32.2
5356	1	16.00	36.00	opalite	4	2.2	0	0.0	1.8
5357	1	13.00	48.00	opalite	3	14.6	0	0.0	6.9
5358	1	11.00	48.00	opalite	16	92.5	0	0.0	0.0
5359	1	5.00	41.00	opalite	18	95.5	2	238.7	473.7
5360	1	2.00	47.00	opalite	8	55.0	0	0.0	17.9
5361	1	24.00	38.00	opalite	6	16.8	0	0.0	29.6
5362	1	24.00	39.00	opalite	10	35.5	0	0.0	2.6
5363	1	31.00	32.00	opalite	2	27.6	0	0.0	35.0
5364	1	37.00	32.00	opalite	5	6.1	0	0.0	28.0
5365	1	24.00	46.00	opalite	13	39.8	0	0.0	13.1
5366	1	23.00	48.00	opalite	16	108.4	0	0.0	20.2
5367	1	33.00	43.00	opalite	3	9.5	0	0.0	0.0
5368	1	32.00	46.00	opalite	5	5.4	0	0.0	14.6
5369	1	44.00	31.00	opalite	2	10.0	0	0.0	10.6
5370	1	43.00	39.00	opalite	3	10.8	1	34.5	85.9
5371	1	52.00	36.00	opalite	3	42.6	0	0.0	18.2
5372	1	59.00	33.00	opalite	34	64.2	0	0.0	87.1
5373	1	44.00	41.00	opalite	1	1.2	0	0.0	1.1
5374	1	40.00	49.00	opalite	31	150.9	1	55.1	69.4
5375	1	56.00	46.00	opalite	7	156.0	0	0.0	13.4
5376	1	53.00	42.00	opalite	11	32.1	0	0.0	159.2
5377	1	66.00	35.00	opalite	18	43.7	0	0.0	10.2
5378	1	62.00	38.00	opalite	37	81.1	0	0.0	11.1
5379	1	61.00	47.00	opalite	24	182.9	0	0.0	2.1
5380	1	65.00	49.00	opalite	25	82.8	0	0.0	52.9
5383	1	23.00	21.00	opalite	1	5.7	0	0.0	0.0
5384	1	24.00	25.00	opalite	1	7.0	0	0.0	69.3
5385	1	32.00	11.00	opalite	0	0.0	0	0.0	65.4

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5386	1	30.00	12.00	opalite	1	4.1	0	0.0	0.0
5387	1	38.00	22.00	opalite	3	1.1	0	0.0	22.2
5388	1	37.00	23.00	opalite	1	15.1	0	0.0	0.0
5389	1	48.00	15.00	opalite	9	29.2	0	0.0	38.5
5390	1	46.00	18.00	opalite	6	20.2	0	0.0	19.6
5391	1	42.00	29.00	opalite	5	6.3	0	0.0	25.7
5392	1	42.00	20.00	opalite	4	28.2	0	0.0	0.0
5393	1	58.00	11.00	opalite	6	20.2	0	0.0	7.2
5394	1	55.00	11.00	opalite	7	84.6	0	0.0	10.0
5395	1	68.00	15.00	opalite	5	30.9	0	0.0	0.0
5396	1	69.00	18.00	opalite	2	1.4	0	0.0	12.8
5397	1	51.00	20.00	opalite	8	53.1	0	0.0	30.9
5398	1	52.00	24.00	opalite	13	48.6	0	0.0	35.3
5399	1	66.00	22.00	opalite	12	23.1	0	0.0	42.3
5400	1	67.00	23.00	opalite	0	0.0	0	0.0	18.6
5401	1	147.00	134.00	opalite	0	0.0	0	0.0	0.8
5402	1	140.00	137.00	opalite	1	1.2	0	0.0	0.0
5403	1	135.00	130.00	opalite	3	3.3	0	0.0	0.0
5404	1	133.00	136.00	opalite	0	0.0	0	0.0	29.1
5405	1	144.00	140.00	opalite	0	0.0	0	0.0	9.4
5408	1	132.00	147.00	opalite	2	13.8	0	0.0	0.6
5409	1	126.00	137.00	opalite	0	0.0	0	0.0	14.2
5410	1	126.00	138.00	opalite	2	1.2	0	0.0	1.5
5411	1	117.00	139.00	opalite	10	39.2	0	0.0	10.5
5412	1	113.00	137.00	opalite	2	0.6	0	0.0	2.0
5413	1	129.00	142.00	opalite	1	0.7	0	0.0	0.0
5414	1	123.00	149.00	opalite	0	0.0	0	0.0	12.0
5415	1	111.00	141.00	opalite	2	3.5	0	0.0	0.0
5416	1	111.00	148.00	opalite	2	1.7	0	0.0	0.0
5418	1	101.00	137.00	opalite	4	9.0	0	0.0	0.0
5419	1	99.00	135.00	opalite	13	23.3	0	0.0	0.0
5420	1	92.00	131.00	opalite	3	4.9	0	0.0	0.0
5421	1	108.00	143.00	opalite	1	0.8	0	0.0	0.0
5422	1	109.00	147.00	opalite	0	0.0	0	0.0	1.1

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5423	1	98.00	144.00	opalite	4	10.5	0	0.0	0.0
5424	1	95.00	146.00	opalite	3	2.9	0	0.0	0.0
5425	1	88.00	138.00	opalite	1	0.4	0	0.0	0.0
5426	1	82.00	132.00	opalite	1	29.7	0	0.0	0.0
5427	1	74.00	135.00	opalite	2	1.0	0	0.0	0.0
5428	1	71.00	136.00	opalite	4	4.9	0	0.0	2.4
5429	1	88.00	143.00	opalite	4	7.5	0	0.0	1.0
5430	1	84.00	148.00	opalite	2	0.8	0	0.0	0.6
5431	1	78.00	146.00	opalite	4	4.8	0	0.0	0.0
5432	1	73.00	146.00	opalite	3	6.6	0	0.0	3.1
5433	1	61.00	131.00	opalite	7	4.6	0	0.0	1.4
5434	1	61.00	138.00	opalite	1	2.9	0	0.0	0.0
5435	1	56.00	131.00	opalite	6	21.8	0	0.0	8.9
5436	1	55.00	135.00	opalite	8	13.4	0	0.0	2.6
5437	1	68.00	141.00	opalite	0	0.0	0	0.0	2.8
5438	1	62.00	146.00	opalite	2	2.3	0	0.0	0.0
5439	1	57.00	147.00	opalite	2	2.6	0	0.0	0.7
5440	1	50.00	149.00	opalite	3	5.3	0	0.0	0.0
5443	1	36.00	132.00	opalite	39	86.9	0	0.0	149.9
5444	1	33.00	138.00	opalite	34	69.7	1	51.1	145.3
5445	1	47.00	148.00	opalite	7	16.3	0	0.0	10.6
5447	1	34.00	147.00	opalite	10	25.1	0	0.0	25.8
5449	1	48.00	150.00	opalite	7	7.4	0	0.0	0.0
5450	1	40.00	157.00	opalite	2	3.5	0	0.0	8.0
5453	1	68.00	156.00	opalite	0	0.0	0	0.0	4.8
5456	1	53.00	159.00	opalite	2	26.2	0	0.0	3.9
5457	1	68.00	166.00	opalite	2	16.1	0	0.0	54.5
5458	1	65.00	165.00	opalite	19	24.2	0	0.0	9.9
5459	1	59.00	169.00	opalite	3	8.0	0	0.0	0.0
5460	1	55.00	168.00	opalite	3	4.9	0	0.0	0.0
5461	1	81.00	151.00	opalite	1	3.4	0	0.0	0.0
5462	1	81.00	153.00	opalite	2	2.0	0	0.0	0.0
5463	1	79.00	157.00	opalite	3	5.2	0	0.0	0.0
5464	1	75.00	155.00	opalite	3	9.3	0	0.0	0.0

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5465	1	88.00	168.00	opalite	1	1.7	0	0.0	0.0
5466	1	80.00	166.00	opalite	4	5.0	0	0.0	0.0
5467	1	77.00	169.00	opalite	4	12.7	0	0.0	5.4
5468	1	71.00	162.00	opalite	2	6.0	0	0.0	0.0
5470	1	105.00	156.00	opalite	4	5.5	0	0.0	0.0
5471	1	99.00	155.00	opalite	2	7.6	0	0.0	0.0
5472	1	90.00	153.00	opalite	5	5.9	0	0.0	0.0
5473	1	106.00	165.00	opalite	0	0.0	0	0.0	26.7
5474	1	102.00	160.00	opalite	2	1.7	0	0.0	0.0
5475	1	95.00	160.00	opalite	2	5.3	0	0.0	0.0
5476	1	94.00	160.00	opalite	2	11.7	0	0.0	0.0
5477	1	128.00	153.00	opalite	2	2.6	0	0.0	0.0
5481	1	119.00	166.00	opalite	1	1.3	0	0.0	0.7
5483	1	113.00	175.00	opalite	2	12.8	0	0.0	0.0
5484	1	112.00	173.00	opalite	1	5.3	0	0.0	0.0
5486	1	102.00	179.00	opalite	3	2.4	0	0.0	0.0
5488	1	91.00	172.00	opalite	12	52.7	0	0.0	4.2
5489	1	87.00	178.00	opalite	17	125.9	0	0.0	36.6
5490	1	83.00	171.00	opalite	2	5.0	0	0.0	0.0
5491	1	78.00	171.00	opalite	2	1.3	0	0.0	0.0
5492	1	77.00	175.00	opalite	3	19.1	0	0.0	0.0
5493	1	68.00	178.00	opalite	5	24.2	0	0.0	5.0
5494	1	60.00	172.00	opalite	7	14.8	0	0.0	0.0
5495	1	51.00	170.00	opalite	2	10.8	0	0.0	0.0
5496	1	50.00	171.00	opalite	1	6.4	0	0.0	2.4
5497	1	17.00	98.00	opalite	10	27.1	0	0.0	0.0
5498	1	14.00	98.00	opalite	6	12.0	0	0.0	2.7
5499	1	16.00	79.00	opalite	4	5.8	0	0.0	3.8
5500	1	14.00	76.00	opalite	8	9.7	0	0.0	0.2
5501	1	8.00	70.00	opalite	4	11.8	0	0.0	0.0
5502	1	7.00	76.00	opalite	9	10.9	0	0.0	0.7
5503	1	18.00	86.00	opalite	37	186.3	0	0.0	34.4
5504	1	14.00	84.00	opalite	15	13.7	0	0.0	1.2
5505	1	2.00	80.00	opalite	3	9.0	0	0.0	0.0

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5506	1	3.00	87.00	opalite	7	23.0	0	0.0	10.1
5507	1	19.00	53.00	opalite	1	0.3	0	0.0	3.1
5508	1	18.00	56.00	opalite	6	33.6	0	0.0	5.5
5509	1	9.00	53.00	opalite	38	70.6	0	0.0	65.8
5510	1	1.00	58.00	opalite	7	6.0	0	0.0	0.7
5511	1	12.00	61.00	opalite	15	23.8	0	0.0	6.4
5512	1	10.00	60.00	opalite	8	54.4	0	0.0	0.0
5513	1	3.00	65.00	opalite	4	8.0	0	0.0	0.3
5514	1	2.00	64.00	opalite	11	7.1	0	0.0	2.2
5516	1	167.00	146.00	opalite	1	0.6	0	0.0	0.0
5518	1	167.00	151.00	opalite	7	23.4	0	0.0	0.0
5519	1	157.00	155.00	opalite	2	14.5	0	0.0	0.0
5520	1	154.00	158.00	opalite	9	29.3	0	0.0	2.3
5521	1	149.00	150.00	opalite	2	9.1	0	0.0	0.0
5522	1	144.00	157.00	opalite	3	1.2	0	0.0	0.0
5523	1	139.00	154.00	opalite	2	9.2	0	0.0	0.0
5524	1	134.00	158.00	opalite	2	3.2	0	0.0	0.0
5525	1	131.00	163.00	opalite	2	2.2	0	0.0	0.0
5526	1	137.00	164.00	opalite	3	0.7	0	0.0	0.0
5528	1	125.00	167.00	opalite	2	1.9	0	0.0	0.0
5529	1	123.00	175.00	opalite	3	6.5	0	0.0	0.0
5530	1	127.00	178.00	opalite	2	2.2	0	0.0	0.0
5531	1	48.00	163.00	opalite	2	22.8	0	0.0	0.0
5532	1	45.00	169.00	opalite	4	14.8	0	0.0	0.0
5533	1	41.00	177.00	opalite	7	11.0	0	0.0	0.0
5534	1	49.00	178.00	opalite	3	2.4	0	0.0	0.0
5535	1	38.00	164.00	opalite	6	12.1	0	0.0	0.0
5536	1	34.00	168.00	opalite	4	16.0	0	0.0	0.0
5537	1	25.00	137.00	opalite	47	107.8	0	0.0	18.7
5538	1	22.00	139.00	opalite	26	63.9	0	0.0	8.3
5539	1	20.00	142.00	opalite	6	6.3	0	0.0	0.0
5540	1	24.00	149.00	opalite	42	64.5	0	0.0	42.6
5545	1	13.00	135.00	opalite	13	20.3	0	0.0	22.5
5546	1	18.00	135.00	opalite	11	10.3	0	0.0	1.9

Table A.2 Debitage data: 25cm by 25 cm systematic random surface scrapes.

Reference #	Specimen #	N	E	Raw material	Flakes and flake fragments n	Flakes and flake fragments wt.(g)	G0 Angular debris n	G0 Angular debris wt.(g)	>G0 Angular debris wt.(g)
5547	1	10.00	121.00	opalite	23	38.6	0	0.0	17.0
5548	1	18.00	121.00	opalite	19	24.5	0	0.0	27.8
5549	1	11.00	110.00	opalite	21	22.6	0	0.0	10.7
5550	1	11.00	110.00	opalite	10	5.3	0	0.0	14.6
5551	1	15.00	107.00	opalite	5	1.7	0	0.0	0.0
5552	1	17.00	100.00	opalite	5	22.3	0	0.0	0.0
5553	1	4.00	96.00	opalite	15	25.7	0	0.0	0.0
5554	1	3.00	92.00	opalite	4	0.9	0	0.0	0.3
5557	1	16.00	10.00	opalite	2	1.3	0	0.0	0.0
5562	1	37.00	7.00	opalite	2	0.9	0	0.0	0.0

Appendix B

List of Illustrated Artifacts

	Figure No.		Reference No.	Specimen No.
Chapter 4	4.1		9141	001
	4.2		6961	001
	4.3	a.	6221	001
		b.	6081	001
	4.4	a.	6221	001
		b.	6221	001
	4.5	a.	6201	001
		b.	6221	001
		c.	9141	001
Chapter 5	5.1	a.	2599	011
		b.	01	099
	5.2	a.	3029	012
		b.	3027	004
		c.	01	081
	5.3	a.	01	062
		b.	01	083
		c.	01	090
		d.	01	082
		e.	01	097 (2 pieces refit)
	5.5	a.	3059	001
		b.	2599	009
		c.	2599	014
		d.	2599	050
	5.6	a.	3097	002
		b.	3012	005
		c.	3032	004
		d.	3029	003
	5.7	a.	3048	001
		b.	2599	080
		c.	6001	002
	5.8	a.	01	011
		b.	3081	003
		c.	8342	001
		d.	3050	005
	5.9	a.	01	110
		b.	01	111
		c.	8301	005
		d.	4007	002
		e.	8392	008

	Figure No.	Reference No.	Specimen No.
	5.10 a.	4083	002
	b.	2599	018
	c.	3065	001
	d.	7721	002
	5.11 a.	3063	001
	b.	5548	002
	c.	01	084
	d.	8041	004
	e.	01	112
	5.12 a.	2599	313
	b.	4463	005
	5.13 a.	01	044
	b.	4022	002
Chapter 6	6.1 a.	01	015
	b.	2599	225
	c.	2599	170
	d.	2599	340
	6.2	2599	203
	6.4 a.	2599	101
	b.	2599	108
	6.5	2599	217
	6.6 a.	2599	363
	b.	2599	362
	c.	2599	361

Appendix C

Technical Analyses

BETA ANALYTIC INC.

MURRY A. TAMERS, PH.D.
JERRY J. STIPP, PH.D.
CO-DIRECTORS

4985 S.W. 74 COURT
MIAMI, FLORIDA
33155 U.S.A.

RECEIVED
MAR 19 1991

March 14, 1991

Mr. Dave N. Schmitt
Intermountain Research
Drawer A
Silver City, Nevada 89428

Dear Mr. Schmitt:

Please find enclosed the results on the nine charcoal samples recently submitted for radiocarbon dating analyses. We hope these dates will be useful in your research.

Your charcoals were pretreated by first examining for rootlets. The samples were then given a hot acid wash to eliminate carbonates. They were repeatedly rinsed to neutrality and subsequently given a hot alkali soaking to take out humic acids. After rinsing to neutrality, another acid wash followed and another rinsing to neutrality. The following benzene syntheses and counting proceeded normally. All of the portions sent for each sample were used for these analyses.

Seven of the samples were small, as indicated on the date report sheet. They were given extended counting time (four times the normal amount) to reduce the statistical errors as much as practical. I should mention that the supplementary fee for the small sample service always includes giving special priority status for the chemical treatments so that we can still meet the promised delivery time.

We are enclosing our invoice. If there are any questions or if you would like to confer on the dates, my direct telephone number is listed below. Please don't hesitate to call us if we can be of help.

Sincerely yours,

Murry Tamers

Murry Tamers, Ph.D.
Co-director

TELEPHONE: 305-667-5167 / FAX: 305-663-0964 / BITNET: XNRBET22@SERVAX

BETA ANALYTIC INC.
(305) 667-5167
UNIVERSITY BRANCH
P.O. BOX 248113
CORAL GABLES, FLA. 33124

REPORT OF RADIOCARBON DATING ANALYSES

FOR: Dave N. Schmitt
Intermountain Research

DATE RECEIVED: February 19, 1991
DATE REPORTED: March 14, 1991
SUBMITTER'S PURCHASE ORDER #

OUR LAB NUMBER	YOUR SAMPLE NUMBER	C-14 AGE YEARS B.P. ±1σ		
Beta-43152	2599-159-6 (Ø.82 gram carbon)	389Ø +/- 7Ø BP	(charcoal)	Trench 3,
Beta-43153	2599-1Ø3-12	27Ø +/- 8Ø BP	(charcoal)	Trench 2,
Beta-43154	2599-1Ø4-13 (Ø.84 gram carbon)	49Ø +/- 7Ø BP	(charcoal)	Trench 2,
Beta-43155	2599-1Ø6-14 (Ø.65 gram carbon)	56Ø +/- 6Ø BP	(charcoal)	T2
Beta-43156	2599-111-18	22Ø +/- 7Ø BP	(charcoal)	bottom T2
Beta-43157	2599-2Ø9-26 (Ø.52 gram carbon)	81Ø +/- 8Ø BP	(charcoal)	bottom T 4
Beta-43158	2599-178-49 (Ø.32 gram carbon)	92Ø +/- 11Ø BP	(charcoal)	T8, E wal
Beta-43159	2599-22Ø-53 (Ø.58 gram carbon)	4Ø9Ø +/- 1ØØ BP	(charcoal)	T5 E end floor
Beta-4316Ø	2599-223-56 (Ø.28 gram carbon)	142Ø +/- 13Ø BP	(charcoal)	T10 E wa

Note: the seven small samples were given extended counting time.

These dates are reported as RCYBP (radiocarbon years before 1950 A.D.). By international convention, the half-life of radiocarbon is taken as 5568 years and 95% of the activity of the National Bureau of Standards Oxalic Acid (original batch) used as the modern standard. The quoted errors are from the counting of the modern standard, background, and sample being analyzed. They represent one standard deviation statistics (68% probability), based on the random nature of the radioactive disintegration process. Also by international convention, no corrections are made for DeVries effect, reservoir effect, or isotope fractionation in nature, unless specifically noted above. Stable carbon ratios are measured on request and are calculated relative to the PDB-1 international standard; the adjusted ages are normalized to -25 per mil carbon 13.

BETA ANALYTIC INC.

MURRY A. TAMERS, PH.D.
JERRY J. STIPP, PH.D.
CO-DIRECTORS

4985 S.W. 74 COURT
MIAMI, FLORIDA
33155 U.S.A.

February 8, 1991

Mr. Dave N. Schmitt
Intermountain Research
Drawer A
Silver City, Nevada 89428

Dear Mr. Schmitt:

Please find enclosed the results on the twenty-four charcoal samples recently submitted for radiocarbon dating analyses. We hope these dates will be useful in your studies.

Your charcoals were pretreated the same as the other materials of this sort submitted previously. They were first examined for rootlets. The samples were then given our acid, alkali, acid soakings to get out carbonates and humic acids. The following benzene syntheses and counting proceeded normally. Beta-42495 was small and this caused the larger than usual statistical error.

We are enclosing our invoice. If there are any questions or if you would like to confer on the dates, please call us.

Sincerely yours,

Murry Tamers

Murry Tamers, Ph.D.
Co-director

P.S. I'm including some sample data sheets for future samples and a copy of our new brochure for your files.

TELEPHONE: 305-667-5167 / FAX: 305-663-0964 / BITNET: XNRBET22@SERVAX

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REPORT OF RADIOCARBON DATING ANALYSES

FOR: Dave N. Schmitt
Intermountain Research

DATE RECEIVED: January 18, 1991
DATE REPORTED: February 8, 1991
SUBMITTER'S PURCHASE ORDER #

OUR LAB NUMBER	YOUR SAMPLE NUMBER	C-14 AGE YEARS B.P. ±1σ	
Beta-42474	2599-160-7	3810 +/- 60 BP	(charcoal)
Beta-42475	2599-161-8	3830 +/- 80 BP	(charcoal)
Beta-42476	2599-162-9	3670 +/- 90 BP	(charcoal)
Beta-42477	2599-107-15	310 +/- 70 BP	(charcoal)
Beta-42478	2599-109-16	370 +/- 50 BP	(charcoal)
Beta-42479	2599-110-17	170 +/- 60 BP	(charcoal)
Beta-42480	2599-112-19	390 +/- 60 BP	(charcoal)
Beta-42481	2599-113-20	230 +/- 70 BP	(charcoal)
Beta-42482	2599-201-21	720 +/- 60 BP	(charcoal)
Beta-42483	2599-205-22	550 +/- 80 BP	(charcoal)
Beta-42484	2599-207-24	620 +/- 90 BP	(charcoal)
Beta-42485	2599-211-28	190 +/- 50 BP	(charcoal)
Beta-42486	2599-213-30	690 +/- 90 BP	(charcoal)
Beta-42487	8001-1-31	330 +/- 50 BP	(charcoal)

These dates are reported as RCYBP (radiocarbon years before 1950 A.D.). By international convention, the half-life of radiocarbon is taken as 5568 years and 95% of the activity of the National Bureau of Standards Oxalic Acid (original batch) used as the modern standard. The quoted errors are from the counting of the modern standard, background, and sample being analyzed. They represent one standard deviation statistics (68% probability), based on the random nature of the radioactive disintegration process. Also by international convention, no corrections are made for DeVries effect, reservoir effect, or isotope fractionation in nature, unless specifically noted above. Stable carbon ratios are measured on request and are calculated relative to the PDB-1 international standard; the adjusted ages are normalized to -25 per mil carbon 13.

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REPORT OF RADIOCARBON DATING ANALYSES

FOR: ______________________

DATE RECEIVED: ______________________

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SUBMITTER'S PURCHASE ORDER # ______________________

OUR LAB NUMBER	YOUR SAMPLE NUMBER	C-14 AGE YEARS B.P. ± 1σ	
Beta-42488	8041-1-33	410 +/- 60 BP	(charcoal)
Beta-42489	8081-1-35	280 +/- 50 BP	(charcoal)
Beta-42490	8161-1-40	310 +/- 60 BP	(charcoal)
Beta-42491	8201-1-42	150 +/- 70 BP	(charcoal)
Beta-42492	2599-165-44	570 +/- 60 BP	(charcoal)
Beta-42493	2599-176-47	500 +/- 50 BP	(charcoal)
Beta-42494	2599-179-50	510 +/- 60 BP	(charcoal)
Beta-42495	2599-224-57	1090 +/- 130 BP	(charcoal)
Beta-42496	2599-114-61	50 +/- 50 BP	(charcoal)
Beta-42497	2599-180-62	520 +/- 70 BP	(charcoal)

These dates are reported as RCYBP (radiocarbon years before 1950 A.D.). By international convention, the half-life of radiocarbon is taken as 5568 years and 95% of the activity of the National Bureau of Standards Oxalic Acid (original batch) used as the modern standard. The quoted errors are from the counting of the modern standard, background, and sample being analyzed. They represent one standard deviation statistics (68% probability), based on the random nature of the radioactive disintegration process. Also by international convention, no corrections are made for DeVries effect, reservoir effect, or isotope fractionation in nature, unless specifically noted above. Stable carbon ratios are measured on request and are calculated relative to the PDB-1 international standard; the adjusted ages are normalized to -25 per mil carbon 13.

BETA ANALYTIC INC.

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CO-DIRECTORS

4985 S.W. 74 COURT
MIAMI, FLORIDA
33155 U.S.A.

Mr. Steven G. Botkin
Intermountain Research
Drawer A
Silver City, NV 89428

September 17, 1990

Dear Mr. Botkin:

Please find enclosed our result on the charcoal sample (3032-36-2599-168) that you recently sent for TIME-GUIDE radiocarbon dating analysis. The date was phoned to you at 10AM this morning. The unused material of pouch 'B' is also returned herein as requested.

The sample contained a minor amount of rootlet contamination. After washing free and discarding all adhering mineral matter the charcoal was lightly crushed for surface area and all remaining rootlets were removed by hand-picking. The charcoal was then treated with soakings in hot acid and alkali solutions to remove any carbonate or humic acid contaminants. After final rinsing to neutrality the clean charcoal was gently dried, synthesized and counted for radiocarbon content. The sample was of very good quality and quantity, and all analytical steps proceeded normally.

We have enclosed our invoice. Would you please forward this to the appropriate office for payment. As always, please call us at any time you have questions or would like to discuss the date.

Sincerely,

Jerry J. Stipp

Jerry J. Stipp

PS: also subtly enclosed is a genuine Beta field cap for your complete protection...and general good luck.

TELEPHONE: 305-667-5167 / FAX: 305-663-0964 / BITNET: XNRBET22@SERVAX

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REPORT OF RADIOCARBON DATING ANALYSES

FOR: Steven G. Botkin
Intermountain Research
Silver City, NV

DATE RECEIVED: September 15, 1990 (10AM)
DATE REPORTED: September 17, 1990 (10AM)
SUBMITTER'S PURCHASE ORDER #

TIME-GUIDE Basis

OUR LAB NUMBER	YOUR SAMPLE NUMBER	C-14 AGE YEARS B.P. ± 1σ	
Beta-39485	3032-36-2599-168	3,890 +/- 60	Charcoal

These dates are reported as RCYBP (radiocarbon years before 1950 A.D.). By international convention, the half-life of radiocarbon is taken as 5568 years and 95% of the activity of the National Bureau of Standards Oxalic Acid (original batch) used as the modern standard. The quoted errors are from the counting of the modern standard, background, and sample being analyzed. They represent one standard deviation statistics (68% probability), based on the random nature of the radioactive disintegration process. Also by international convention, no corrections are made for DeVries effect, reservoir effect, or isotope fractionation in nature, unless specifically noted above. Stable carbon ratios are measured on request and are calculated relative to the PDB-1 international standard; the adjusted ages are normalized to -25 per mil carbon 13.

July 22, 1991

Ms. Kathryn Ataman
Intermountain Research
Drawer 'A'
Silver City, NV 89428

Dear Ms. Ataman:

Enclosed below is a table presenting x-ray fluorescence data generated from the analysis of six artifacts from site 26Ek3032 in the Tosawihi quarries area, Elko County, Nevada. The analyses were conducted pursuant to your letter request of July 18, 1991.

X-ray fluorescence analysis conditions and artifact-to-source assignment procedures for these six samples were identical to those I reported to Dr. Elston in my letter of February 14, 1991.

Trace Element Concentrations

Cat. Number	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba*	Obsidian Source (Chemical Type)
Loc. 36, 3063-1	80 ±7	18 ±4	375 ±5	2 ±3	82 ±3	74 ±5	17 ±3	0 ±24	Paradise Valley
Loc. 36, 8041-4	74 ±6	24 ±3	368 ±5	2 ±3	80 ±2	74 ±5	13 ±3	0 ±13	Paradise Valley
Loc. 36, 01-112	70 ±6	19 ±3	212 ±5	41 ±3	66 ±2	401 ±5	45 ±3	1117 ±14	Browns Bench
Loc. 23, 3001-1	54 ±6	20 ±3	249 ±5	26 ±3	68 ±2	367 ±5	46 ±3	625 ±13	Browns Bench
Loc. 138, 53-1	78 ±6	15 ±4	179 ±5	64 ±3	71 ±2	556 ±6	53 ±3	1228 ±14	Browns Bench
Loc. 141, 01-1	68 ±5	20 ±3	361 ±5	0 ±3	74 ±2	74 ±5	11 ±3	0 ±13	Paradise Valley

All trace element values in parts per million (ppm); ± = pooled expression (in ppm) of x-ray counting uncertainty and regression fitting error at 200 and 300* seconds livetime.

Trace element data in the table document that three of these samples match the geochemical signature of parent obsidians of the Paradise Valley geochemical type, and three correspond with the trace element profiles of Browns Bench volcanic glass. In my letter of February 14, I remarked that Browns Bench obsidian is somewhat variable in trace element composition because it was formed in a large ash-flow tuff sheet. Such sheets can produce artifact-quality glasses that vary in geochemical composition both horizontally and vertically.

I hope these data will be of assistance in your analysis of the Tosawihi materials. Please contact me at my laboratory (Phone: [916] 364-1074) if I can provide further assistance.

Sincerely,

Richard Hughes

Richard E. Hughes, Ph.D.

SONOMA STATE UNIVERSITY ACADEMIC FOUNDATION, INC.

ANTHROPOLOGICAL STUDIES CENTER
CULTURAL RESOURCES FACILITY
707 664-2381

Dr. Kathryn Ataman
Intermountain Rseearch
Drawer A
Silver City, Nevada 89428

August 16, 1991

Dear Dr. Ataman:

This letter reports our analysis of hydration bands on six obsidian items from site 26EK3032. This work was completed as requested in your letter dated July 24, 1991.

The analysis was completed at the Sonoma State University Obsidian Hydration Laboratory, an adjunct of the Anthropological Studies Center, Department of Anthropology. Procedures used by our hydration lab for thin section preparation and hydration band measurement are described below.

Each specimen was examined in order to find two or more surfaces that would yield edges which would be perpendicular to the microslide when preparation of the thin section was completed. Two small parallel cuts were made at an appropriate location along the edge of each specimen with a 4 inch diameter circular saw blade mounted on a lapidary trimsaw. The cuts resulted in the isolation of a small sample with a thicknesses of approximately one millimeter. Each sample was removed from its specimen and mounted with Lakeside Cement onto permanently etched petrographic microslide.

The thickness of the samples was reduced by manual grinding with a slurry of #500 silicon carbide abrasive on a glass plate. The grinding was completed in two steps. The first grinding was terminated when the sample's thickness was reduced by approximate 1/2, thus eliminating any micro-chips created by the saw blade during the cutting process. The slides were then reheated, which liquified the Lakeside Cement, and the samples inverted. The newly exposed surfaces were then ground until the proper thickness was attained.

The correct thin section thickness was determined by the "touch" technique. A finger was rubbed across the slide, onto the sample, and the difference (sample thickness) was "felt." The second technique employed for arriving at proper thin section thickness is termed the "transparency" test. The microslide was held up to a strong source of light and the translucency of the thin section observed. The sample was sufficiently reduced in thickness when the thin section readily allowed the passage of light.

A protective coverslip was affixed over the thin sections when all grinding was completed. The completed microslides are curated at our hydration lab under File No. 91-H1044.

1801 East Cotati Avenue Rohnert Park, California 94928

The hydration bands were measured with a strainfree 40 power objective and a Bausch and Lomb 12.5 power filar micrometer eyepiece on a Nikon petrographic microscope. Six measurements were taken at several locations along the edge of the thin section. The mean of the measurements was calculated and listed on the enclosed table with other information. These hydration measurements have a range of +/- 0.2 due to normal limitations of the equipment.

One specimen (23-3001-35), as marked on the table by the abbreviation "DH" under the "Mean" column, has diffuse hydration which is not measureable.

If you have questions or comments about this hydration work, please don't hesitate to contact us.

Cordially,

Thomas M. Origer

Thomas M. Origer, Director
Obsidian Hydration Laboratory

NV-26EK3032 Submitted by: Kathryn Ataman - Intermountain Research August 1991

Lab#	Catalog#	Description	Provenience	Remarks	Measurements (microns)	Mean	Source
01	23-3001-35	Biface fragment	surface	none		DH	BB (x)
02	36-3063-1	Rosegate point	surface	none	1.4 1.4 1.4 1.6 1.6 1.7	1.5	PV (x)
03	36-8041-4	Gatecliff series	surface	none	2.5 2.5 2.5 2.5 2.6 2.6	2.5	PV (x)
04	36-01-112	Biface fragment	surface	none	10.1 10.3 10.3 10.3 10.4 10.4	10.3	BB (x)
05	138-53-1	Point stem	surface	none	11.0 11.1 11.1 11.2 11.3 11.3	11.2	BB (x)
06	141-01-1	Preform?	surface	none	4.1 4.2 4.2 4.3 4.3 4.3	4.2	PV (x)

Lab Accession No.: 91-H1044 Technician: Thomas M. Origer